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An evolutionary patch pattern approach for texture discrimination

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Abstract

A new evolutionary approach is presented, based on implicit pattern–process relationships. For implementing this approach, any gray level texture image is decomposed into a progressive sequence of binary patch patterns that describe a process of change from background to foreground domination. Each of the binary patterns throughout these sequences is parameterized, using several metrics that describe, for example, its fragmentation level, both for the background (e.g., white) and foreground (e.g., black) patch patterns. Any texture type is then assumed to have a unique evolutionary path represented by a distinctive region in the feature space of metrics characterizing these patterns and their change. Application of hierarchical clustering based on a few (3 or 4) metrics representing characteristic stages in the patterns' change process allowed us to accurately discriminate between 50 samples of 10 Brodatz texture types.

Keywords: Patch patterns; Spatial dynamics; Spatial duality; Texture discrimination

1. Introduction

Remote sensing images are rich in texture (Fig. 1), especially with the influx of new high-resolution satellite sensor systems that provide multi-spectral data with sub-meter pixel size. Texture and pattern analysis techniques are fundamental for extracting spatial information from these data sources [1,2]. Numerous algorithms are available for this purpose, most of which originate from a "vision" perspective (e.g., [3–5]). Here, another perspective is revealed, namely, viewing images as ontological instruments for capturing surface dynamics [6]. Extracting this dynamics from a "snap-shot" image may facilitate implementing a process-based approach for the texture and pattern discrimination task. Although gray levels might be used to represent the surface' dynamics, in the case of vegetation for example, they refer to patch entities that are created, expanded, aggregated, split, and annihilated in parallel, jointly forming most variable patterns.

Landscape ecology employs various methods for parameterizing patch pattern (PP) dynamics (e.g., [7–9]). The majority of these methods are fundamentally similar to statistical and structural texture analysis techniques (e.g., [3–5]). Recently, two new approaches were integrated for studying PP in the ecological context: (1) implicit reconstruction of PP evolution from single-date photograph [10], and (2) a spatial duality approach for characterizing changes in patterns, based on combining both the foreground and background (vegetation and soil, in our example) information [11,12]. In this article, we further extend the use of this integrative approach as a general purpose texture feature extraction technique for facilitating discrimination between regions of homogenous image textures. When implementing this approach to scenes of man-made, synthetic, or static patterns, their images are considered to represent pseudo-dynamics, with the ecological perspective as a metaphor.

This article is structured as follows: implicit reconstruction and spatial duality will be first explained and demonstrated, then discussed with reference to existing texture analysis techniques; and finally, the new integrative approach will be implemented for classifying images of natural as well as artificial texture scenes.

2. PP dynamics and gray level pattern evolution

"Time–Space transformation" is rather an old scientific concept (e.g., [13,14]); it enables one to extract temporal

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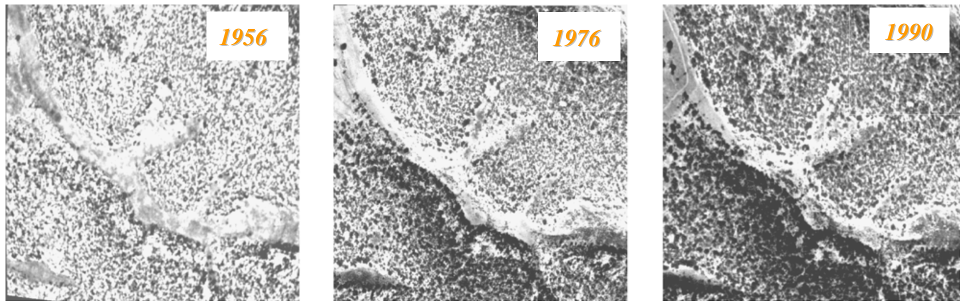

Fig. 1. Temporal texture variation in historical air photographs representing vegetation pattern dynamics in a semi-arid site in Southern Israel.

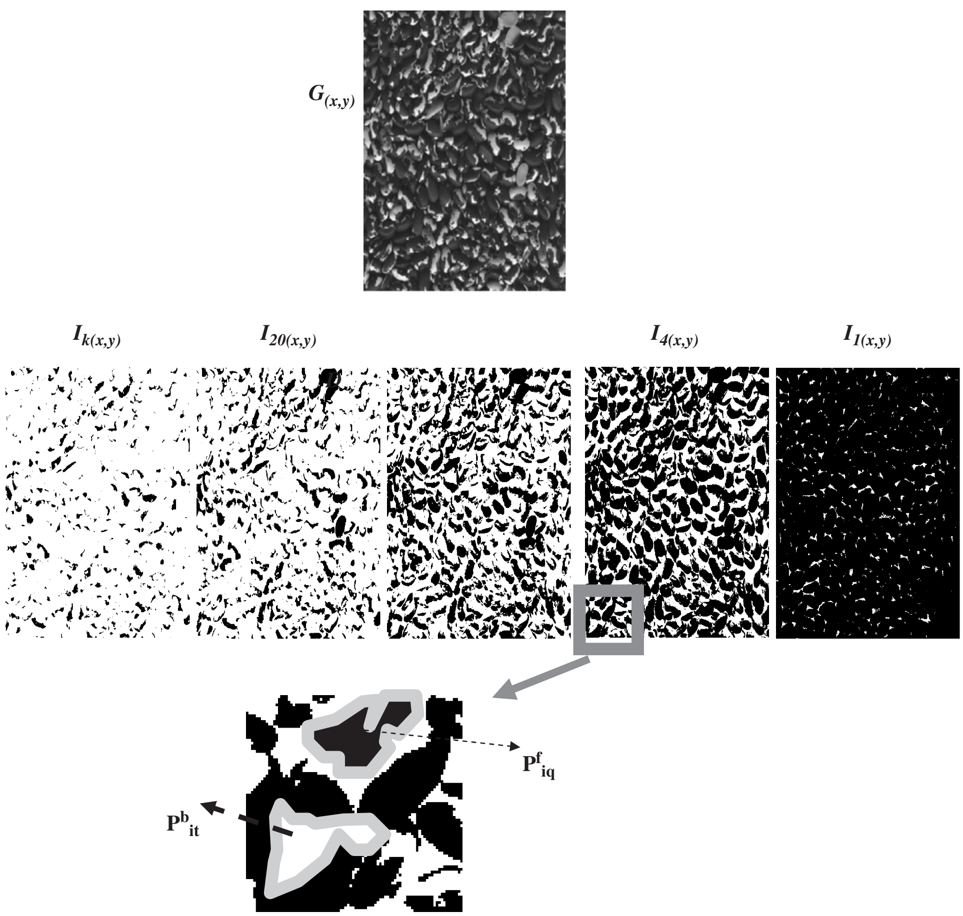

Fig. 2. Application of the progressive partitioning algorithm on a gray level texture image $\boldsymbol{G}(x, y)$ producing a sequence of binary images $(\boldsymbol{I}_1(x, y) \ldots \boldsymbol{I}_i(x, y) \ldots \boldsymbol{I}_k(x, y))$ from which foreground and background patches are delineated ($P^{\mathrm{f}}_{i_q}$ and $P^{\mathrm{b}}_{i_t}$).

information from spatial variations and vice versa. This is needed in order to overcome the lack of detailed and extended temporal data records, for example, in the case of utilizing air photographs for extracting PP information. Due to availability constraints, air photographs, which are an important information source for studying PP, are inherently limited in providing adequate coverage of vegetation dynamics fluctuating at monthly to decadal cycles [11,15]. Implicit reconstruction of PP dynamics from single-date historical air photographs was proposed by Ref. [10] as a partial solution to this problem, assuming that spatial dynamics is embedded to a certain extent within a "snap-shot" image of the processes taking place. According to this approach, brightness gradients are regarded as representing the "memory" of past patterns and processes in the ecosystem: on the one hand, soil "color" becomes "lighter" as a function of the time elapsed since the soil was last covered by vegetation; on the other hand, vegetation color becomes darker at their core areas, as shrubs expand and grow. For the purpose of extending the relevance of this work to other types of real or pseudo-dynamics, the terminology applied hereon refers to background and foreground as a generalization of the soil and vegetation surface dynamics (correspondingly). Such