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A completely automatic spectral rule-based preliminary classification of calibrated Landsat 5 TM and Landsat 7 ETM+ images scalable to ASTER, AVHRR, MODIS, SPOT-4, SPOT-5, and SPOT VEGETATION imagery

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Image classification methods

Abstract

In recent years the launch of (very) high-resolution (VHR) spaceborne multi-spectral (MS) scanners has made purely supervised remote sensing (RS) image analysis over extended target areas no longer feasible as reference data are difficult, tedious, or expensive to gather.

To overcome limitations of a purely supervised classification approach to RS image classification problems, a two-stage hybrid learning classification scheme can be recommended. In this context, a novel spectral prior knowledge-based preliminary classifier (suitable as a hybrid learning first-stage classifier) is presented hereafter.

The main operational and architectural properties of the proposed rule-based classifier are summarized below.

- It is input with Landsat 5 TM and Landsat 7 ETM+ images calibrated into planetary reflectance (albedo) and at-satellite temperature.
- It is fully unsupervised, i.e, it requires:
  - no free parameter to be user-defined and
  - no reference (supervised) data set of examples.
- It is pixel-based. As a consequence, it is computationally efficient, requiring approximately 15 minutes per Landsat scene (from data calibration to output map generation).
- It is robust to changes in the input data set, i.e., it is capable of dealing with the inherent fuzziness (variability) of class-specific spectral signatures. As a consequence, unlike traditional (e.g., maximum likelihood) pixel-based classifiers, it

is not affected by salt-and-pepper classification noise effects.

- It consists of a dictionary of spectral signatures implemented as a set of fuzzy rules based on prior spectral knowledge. The spectral resolution of these fuzzy rules is assumed to be that of Landsat 5 TM and Landsat 7 ETM+ imagery. As a consequence, these fuzzy rules are scalable to other sensors' spectral properties (e.g., ASTER, AVHRR, MODIS, SPOT-4 and -5, SPOT VEGETATION, etc.)
- The fuzzy rule-based pixel classification consists of two processing levels.

  - The first stage matches each pixel-based input data vector with a dictionary of reference spectral signatures modeled as a logical (and, or) combination of inter-band relative relationships (e.g., band 1 greater than band 2) provided with tolerance intervals.

  - The second stage matches each pixel-based input data vector with a dictionary of reference spectral signatures modeled as a logical (and, or) combination of fuzzy sets (e.g., band 1 is high). These fuzzy sets provide a so-called irregular but complete grid-partition of the input feature space.

- In its current version, the implemented system detects up to 72 output spectral categories (types, or strata) suitable for the preliminary mapping (baseline map, primal sketch, in the Marr sense) of RS imagery. In particular,

  - Several spectral categories belong to class *Vegetation.*
  - Several spectral categories belong to class *Rangeland.*
  - Several spectral categories belong to class *Bare soil* and *Built-up areas.*
  - Several spectral categories belong to class *Water.*
  - Several spectral categories belong to class *Clouds.*
  - Several spectral categories belong to classes *Snow* and *Ice.*
  - Spectral category *Pit bogs.*
  - Spectral category *Greenhouses.*
  - Spectral category *Unknowns.*

- The symbolic meaning of kernel spectral categories (e.g., StrongVegetation) is intermediate between those (low) of clusters and segments and those (high) of land cover classes (e.g., forest). This means that the application domain of kernel spectral strata is by no means alternative to RS data clustering, image segmentation, and land cover classification. Rather, prior knowledge-based kernel spectral categories are naturally suitable for driving stratified application-specific classification, clustering, or segmentation of RS imagery which could involve training and supervision.

The accuracy, robustness, and computational efficiency of the proposed rule-based system, plus its consistency with the CORINE 2000 Land Cover classification scheme (CLC00), are assessed in several operational RS image classification problems.