Object-based Land Cover Classification for Pyongsan Uranium Mine and Concentration Plant using Machine Learning Based Classifier

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Introduction

- **Objectives**
  - To evaluate the feasibility of the machine learning based classification method, i.e., SVM, with MNDWI for monitoring the suspicious nuclear proliferation activities in a restricted AOI (Area of Interest).

- **Need for the computer-based image analysis (classification)** to support imagery analysts’ interpretation
  - To minimize time and cost for analysts’ interpretation, the computer-based image analysis analysis has been indispensable in recent years.
  - If a land cover of AOI can be classified according to its use, it is possible to determine whether or not a suspected facility regarding nuclear proliferation is in operation.

- **SVM (Support Vector Machine)**
  - Based on machine learning with training sets of the user-defined classes, SVM separates the classes with the optimal hyperplane which maximizes the margin between the classes (C.-W. Hsu et al., 2010).
  - Further, eCognition®, which is the representative software solutions for image analysis, offers machine-based classifier including the decision tree and the SVM.

- **MNDWI (Modification Normalized Difference Water Index)** (Xu, 2006)
  - With the multispectral satellite image including the short-wave infrared (SWIR), MNDWI can describe the spectral characteristics of open water bodies.

Methodology

- **AOI: Pyongsan uranium mine and concentration plant**
  - The Pyongsan uranium mine and concentration plant in one of North Korea’s largest declared uranium ore concentrate facilities, where uranium ores are mined and milled to yellowcake (UO₂).
  - With analyzing satellite imagery, J. Bermudez (CSIS Beyond Parallel, 2020) estimated that the plant was still in operation by detecting some changes around the facilities.

- **Object-based land cover classification methodology using the SVM classifier and MNDWI**
  1) To correct the radial and the geometric distortions, pre-processing was performed using the Gram-Schmidt pan-sharpening and the image-to-image registration.
  2) Multi-resolution segmentation was applied to segment the pre-processed satellite image.
  3) Samples for training of the SVM classifier were selected among the image objects according to the pre-defined object classes.
  4) SVM algorithm (machine learning based classification) embedded in eCognition® were utilized to classify the image objects to 5 classes with the samples.
  5) Reclassification with MNDWI of Xu (2006) was carried out to differentiate water bodies from misclassified classes.

Results and Conclusions

- **Object-based land cover classification result for AOI**
  - Multi-resolution segmentation result of AOI
    - In this study, the multi-resolution segmentation algorithm in eCognition® was applied to consider all the spectral information of 16 bands of the WorldView-3 satellite image.
    - The blue are the boundaries surrounding image objects regarded as the homogeneous pixels with the homogeneity criteria: scale (100), shape (0.5), and compactness (0.5).
  - Selected samples for the five pre-defined object classes
    - Among the image objects (segments) in the segmentation result, sample objects for training of the SVM classifier were selected according to the 5 object classes.

- **Classification using the SVM classifier**
  - The SVM classifier trained with above samples was utilized to classify all the image object into 5 classes.
  - This study carried out the reclassification with MNDWI of Xu (2006) in the equation below. As shown in the figure above, image objects classes indicating MNDWI over the empirical threshold, i.e., 0.4, were classified as water bodies (blue).

\[
MNDWI = \text{Green} - \text{SWIR} \\
\text{Green} + \text{SWIR}
\]

where Worldview band 3 (green band, 510 to 580 nm) and band 11 (SWIR-3 band, 1,640 to 2,680 nm) was used for Green and SWIR in this study, respectively.

- **Future works**
  - The accuracy of classification will be quantitatively analysed with the proper accuracy indices for countering nuclear proliferation.
  - The change detection for the uranium ore distribution will be performed using the accumulated land cover classification results.

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