Transfer Learning for Cloud Screening in Satellite Imagery

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Accurate and automatic detection of clouds in optical satellite scenes is a key issue for a wide range of remote-sensing applications. With no accurate cloud masking, undetected clouds are one of the most significant sources of error in both sea and land biophysical parameter retrieval.

Cloud masking is a semantic segmentation problem where a cloud flag for each pixel must be provided. Convolutional neural networks (CNN) have shown an excellent performance on this problem provided enough labeled data. However, simultaneous collocated information about the presence of clouds within an image is usually not available or requires a great amount of manual labor.

In this work [Mateo-García and Gómez-Chova, 2018], we propose to learn from the available Landsat-8 satellite cloud masks datasets and transfer this learning to solve cloud detection problems in new satellites such as the Proba-V vegetation monitoring satellite.

Problem Statement
- Current operational cloud detection algorithms are designed specifically for each new satellite.
- The number of earth observation optical satellites is growing exponentially.
- Supervised machine learning approaches need a statistically significant amount of manually labeled images to learn from.
- The NASA released the largest manually labeled cloud mask archive for their Landsat missions [Foga et al., 2017].
- The current operational Proba-V cloud detection algorithm has poor performance in many situations [Iannone et al., 2017].

Research Questions
- Can we reuse Landsat datasets to create a cloud detection algorithm for Proba-V?
- If we have labeled images from both sensors, will Landsat 8 imagery help to improve cloud detection performance?

Transfer Learning

Landsat 8
11 spectral bands  
30m spatial resolution

Spatial resampling

Manual Cloud mask

Simulated cloud mask

Proba-V
4 spectral bands  
333m spatial resolution

Spatial resampling

We propose to transform the images from the released Landsat 8 datasets to resemble Proba-V images. With this simulated dataset we trained a fully convolutional CNN (UNet) and we tested it in real Proba-V images. In addition, we fine-tuned this CNN using real Proba-V images.

Landsat 8 Biome Dataset
96 images (8000 x 8000 pixels approx.) manually labeled by NASA experts.

Proba-V Dataset
72 Proba-V images manually labeled (5000 x 5000 pixels approx.) from four days over the four seasons:
- 48 train.
- 24 test.

CNN Architecture

Fully convolutional UNet architecture adapted from [Ronneberger et al., 2015]

Experimental results

Results over test Proba-V images

<table>
<thead>
<tr>
<th>Validation Results</th>
<th>Operational V101</th>
<th>CNN PV v101</th>
<th>CNN FT V101</th>
<th>CNN Landsat 8</th>
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<tbody>
<tr>
<td>Accuracy %</td>
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<td>Kappa</td>
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</tr>
</tbody>
</table>

Differences between ground truth and predictions. In white agreements between cloud masks, in blue pixels manually labeled as cloud-free and predicted as cloud-free (omission errors), in orange pixels manually labeled as cloudy and predicted as cloudy (commission errors). In purple pixels manually labeled as cloudy and predicted as cloudy-free (commission errors).

Conclusions
- CNN model trained only with adapted Landsat 8 data outperforms operational Proba-V algorithm.
- Combining the data of both satellites yields new state-of-the-art results.

References

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Image 1: Landsat 8 (11 spectral bands, 30m spatial resolution) and Proba-V (4 spectral bands, 333m spatial resolution).

Image 2: Manual Cloud mask and Simulated cloud mask.

Image 3: Results over test Proba-V images.