Segmentation of Crop Field Parcels in Switzerland Using Satellite Imagery

Developing a Crop Field Segmentation and Visualization Framework with U-Nets Using Sentinel-2 Imagery

Student

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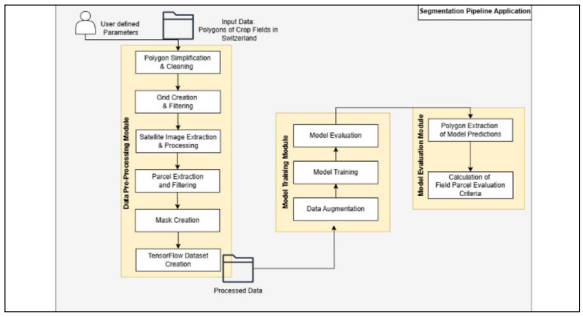
Introduction: Rapid population growth and the consequent surge in food demand drive agricultural expansion, significantly altering land use. As a result, acquiring precise spatial data on crop field parcels has become critical for governments in efficiently allocating subsidies and enforcing regulations. A vital part of this effort is identifying crop field boundaries. However, this has traditionally been a labor-intensive and time-consuming task. For example, in Switzerland, the government requires farmers to submit geo-referenced polygons for their fields once at the beginning of the crop year. Since this parcel data is manually collected and subject to modification (changes in weather or planning), evaluating its accuracy and reliability is crucial.

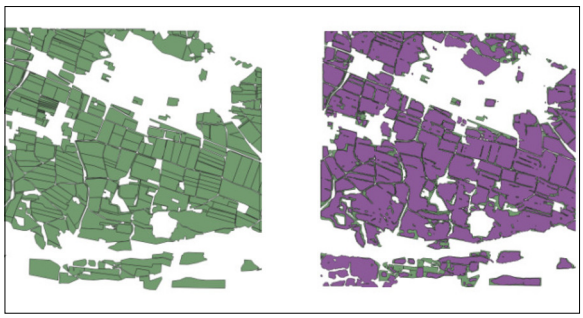
Problem: Deep Learning (DL) offers a modern solution, revolutionizing agricultural science through cutting-edge image processing and data analysis techniques. Moreover, the availability of multispectral high-resolution satellite imagery has been a driving force in the widespread adoption of DL, providing up-to-date and accurate data. Semantic Segmentation, a popular DL computer vision method, has been utilized in numerous studies on crop field segmentation. Given its unique agricultural landscape however, Switzerland has been largely absent from many existing studies. In addition, a critical gap remains in the standardization of evaluation methods for field parcel segmentation results. As such, herein lies an opportunity for new research.

Approach: This project implements a DL-based crop field segmentation framework. This framework employs various DL U-Net architectures designed for crop field parcel segmentation. Specifically tailored to Switzerland's field parcel data, the framework leverages geospatial techniques for data cleaning/simplification, satellite image extraction, data pre-processing, and augmentation. Custom evaluation criteria were developed in this project to efficiently measure the performance of the algorithms and ensure clarity for experts in the agricultural / geoinformatic field. An interactive web interface has also been designed to facilitate comprehensive model assessment through visual analysis of diverse segmentation metrics. Numerous experiments have been conducted to assess the framework's efficiency in segmenting crop field parcels. This performance has been evaluated on a test dataset. The findings show, that the Standard U-Net and Attention U-Net performed the best with a 90% accuracy. Satellite data augmentation and upscaling, however, had no significant impact on performance. Additionally, increasing model complexity and thereby enhancing relevant feature extraction during training did not, as expected, result in improved accuracy. This study further investigated and successfully identified problematic crop field use types and cantons, which do not perform as expected. Additionally, a 15% total average error on the Swiss dataset and a 16% error on the test dataset indicate that the U-Net generalizes well to unseen data but faces challenges in accurately identifying certain crop-field types. The discussion and analysis suggest that this error is likely due to factors such as data recording inaccuracies and changes in agricultural practices by farmers.

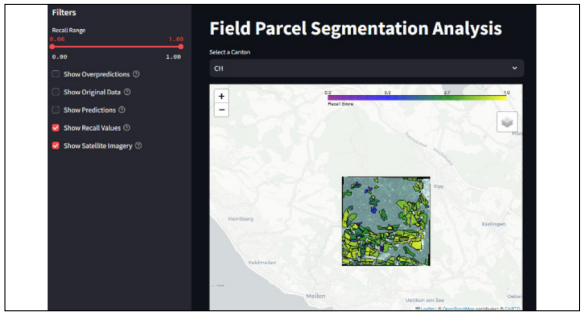
SPA - The Segmentation Pipeline Application
Own presentment



Original Crop Field Parcels (Green) & Model Predictions (Purple)
Own presentment



DVA - The Data Visualizer Application
Own presentment



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