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servir-aces: A Python Package for Training Machine Learning Models for Remote Sensing Applications

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Summary

servir-aces Agricultural Classification and Estimation Service (ACES) is a Python package for generating training data using highly parallelized apache-beam and Google Earth Engine (GEE) (Gorelick et al., 2017) workflows as well as for training various Machine Learning (ML) and Deep Learning (DL) models for Remote Sensing Applications (Mayer et al., 2023), (Bhandari & Mayer, 2024).

Statement of Need

Despite robust platforms, specialized technical knowledge is required to setup and run various ML/DL models, leading many practitioners, scientists, and domain experts to find it difficult to implement them. The **servir-aces** Python package is created to fill this gap. **servir-aces** siginicantly lowers the barrier for users to export training data and both train and run DL models using cloud-based technology with their GEE workflows. Several examples are provided via a runnable notebook to make it easier for scientists utilize this emerging field of DL.

With petabytes of data available via GEE, and integration of the TensorFlow (TF) platfrom, models trained in TF can be easily loaded into GEE. This package provides functionalities for 1) data processing; 2) data loading from GEE; 3) feature extraction, 4) model training, and 5) model inference. The combination of TF and GEE has enabled several large scale ML and DL Remote Sensing applications. Some of them include Wetland Area Mapping (Bakkestuen et al., 2023), Crop Type Mapping (Poortinga et al., 2021), Surface Water Mapping (Mayer et al., 2021), and Urban Mapping (Parekh et al., 2021). However, these applications tend to be developed ad-hoc without using a common library and require a very specialized domain as well as technical knowledge. In addition, several unified libraries like torchgeo (Stewart et al., 2022) and rastervision exists but those are mostly targeted for pytorch user community. Some efforts for GEE & TensorFlow users stemmed out of geemap (Wu, 2020) but that is mostly for tree based approaches like Random Forest, while geospatial-ml has not seen much development since its inception. Thus there is a need for a unified libraries to train deep learning models within the GEE & TensorFlow user community. The **servir-aces** is a first step for that. Although this was originally deeloped for agricultural related applications, the library has matured enough to work for any kind of image segmentation tasks.

servir-aces Audience

servir-aces is intended for development practitioner, researchers, and students who would like to utilize various freely available Earth Observation (EO) data using cloud-based GEE and TF ecosystem to perform large scale ML/DL related Remote Sensing applications.

We also provide several notebook examples to showcase the usage of the **servir-aces**. Here we show how **servir-aces** can be used for crop-mapping related application. Ideally, the same process can be repeated for any kind of the image segmentation task.

servir-aces Functionality

The major high-level functionality of the **servir-aces** packages are: - Data loading and processing from GEE. - Generation of training data for various ML and DL models. - Training and evaluation of ML/DL Models. - Inferences of the trained ML/DL models. - Support for remote sensing feature extraction. - Integration with Apache Beam for data processing and parallelization.

The key functionality of **servir-aces** is organized into several modules:

- data_processor: this module provides functionality for data input/output and preprocessing for the image segmentation project.
- model_builder: this module provides functionality for creating and compiling various Neural Network Models, including DNN, CNN, U-Net.
- model_trainer: this module provides functionality for training, buidling, compiling, and running specified deep learning models.
- metrics: this module provides a host of statstical metrics, standard within the field, for evaluating model performance and provide utility functions for plotting and visualizing model metrics during training.
- ee_utils: this module for providing utility functions to handle GEE API information and authentication requests.
- remote_sensing: this module provides various static methods to compute Remote Sensing indices for analysis.

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References

Bakkestuen, V., Venter, Z., Ganerød, A. J., & Framstad, E. (2023). Delineation of wetland areas in south norway from sentinel-2 imagery and LiDAR using TensorFlow, u-net, and google earth engine. *Remote Sensing*, *15*(5), 1203.

Bhandari, B., & Mayer, T. (2024). Comparing deep learning models for rice mapping in bhutan using high resolution satellite imagery. *ISPRS Open Journal of Photogrammetry and Remote Sensing*, *to appear*, to appear.

Gorelick, N., Hancher, M., Dixon, M., Ilyushchenko, S., Thau, D., & Moore, R. (2017). Google earth engine: Planetary-scale geospatial analysis for everyone. *Remote Sensing of Environment*, *202*, 18–27.

Mayer, T., Bhandari, B., Martínez, F. G., Walker, K., Jiménez, S. A., Kruskopf, M., Maganini, M., Phalke, A., Wangchen, T., Phuntsho, L., & others. (2023). Employing the agricultural classification and estimation service (ACES) for mapping smallholder rice farms in bhutan. *Frontiers in Environmental Science*, *11*, 1137835.

Mayer, T., Poortinga, A., Bhandari, B., Nicolau, A. P., Markert, K., Thwal, N. S., Markert, A., Haag, A., Kilbride, J., Chishtie, F., & others. (2021). Deep learning approach for sentinel-1 surface water mapping leveraging google earth engine. *ISPRS Open Journal of Photogrammetry and Remote Sensing*, *2*, 100005.

Parekh, J. R., Poortinga, A., Bhandari, B., Mayer, T., Saah, D., & Chishtie, F. (2021). Automatic detection of impervious surfaces from remotely sensed data using deep learning. *Remote Sensing*, *13*(16), 3166.

Poortinga, A., Thwal, N. S., Khanal, N., Mayer, T., Bhandari, B., Markert, K., Nicolau, A. P., Dilger, J., Tenneson, K., Clinton, N., & others. (2021). Mapping sugarcane in thailand using transfer learning, a lightweight convolutional neural network, NICFI high resolution satellite imagery and google earth engine. *ISPRS Open Journal of Photogrammetry and Remote Sensing*, *1*, 100003.

Stewart, A. J., Robinson, C., Corley, I. A., Ortiz, A., Lavista Ferres, J. M., & Banerjee, A. (2022). TorchGeo: Deep learning with geospatial data. *Proceedings of the 30th International Conference on Advances in Geographic Information Systems*, 1–12. https://doi.org/10.1145/3557915.3560953

Wu, Q. (2020). Geemap: A python package for interactive mapping with google earth engine. *Journal of Open Source Software*, *5*(51), 2305. https://doi.org/10.21105/joss.02305