Combining computer vision and satellite imagery to detect center pivot irrigation

Ashley Grinstead, Evan Bui, Tiffany Hsu, Tristan Chen
Earth Research Institute Sponsor: Dr. Kelly Caylor Mentors: Leron Reznikov & Anna Boser
UC SANTA BARBARA

Introduction

- The **Earth Research Institute (ERI)** at UCSB spans areas covering natural hazards, human impacts, earth system science, and earth evolution by collaborating across interdisciplinary departments on campus. Under the guidance of Kelly Caylor (Director of ERI and WAVES lab), we are undertaking a project to explore how center pivot-irrigated agriculture is expanding globally.
- Irrigated agriculture is expanding rapidly across southern Africa. Because this expansion is occurring without much regulation or monitoring, it's not exactly clear where and when expansion is happening, or the fate of expanded agriculture. In most expansionary cycles, there is a boom-and-bust dynamic, where many investments fail quickly and only a few persist.
- We're interested in mapping these dynamics over the recent years and monitoring them going forward.

Key terms

- **Center Pivot Irrigation**: This is an effective method of crop irrigation in which crops are watered by a circular pattern around a central pivot point.
- **AOI**: Areas of Interest
- **Semantic Segmentation**: Semantic image segmentation is a computer vision task where we separate and label specific parts of an image according to what is shown. The goal of this task is to label each pixel of an image with a corresponding class of what's being shown.

Methodology

- **Image Formats:** Each monthly image quad is saved as a TIF and a JPG image. The JPEG image is imported into LabelStudio for labeling. TIF stands for tag image file. The TIF format is used because the Planet data has more than three bands (RGB) and this extra information could be used for training.
- **Full Center Pivots only:** We have decided to only label Full Center Pivots. In some of the areas in the data we chose to label, there existed Partial Center Pivots. These partial center pivots somewhat overlapped creating a pac-man like shaped center pivot besides a full center pivot.
- **Transfer Learning:** A method where a developed model is used as a starting point for a model for a new task. Here we decided to start training with our data on a model that was already trained on center pivots.
- The model that we mainly tested our data on was a **U-NET segmentation model**.
  - U-NET is a type of convolutional neural network that was developed for better image segmentation
  - The model is separated into 2 paths: the contracting path, which is similar to a typical CNN, and the expansion path, which consists of layers of up-convolutions and concatenations
  - U-NET excels at pixel-wise classification and can perform with fewer images.
- **Evaluation Metrics for Semantic Segmentation**
  - Intersection over Union: Takes the area of overlap between the predicted pixels and the labeled pixels (intersection) over the area that both the predicted pixels and labeled pixels cover (union).
  - IoU = TP / TP + FP + FN = Area of Overlap / Area of Both

Exploratory Analysis

Figure 1: This figure shows the process of labeling center pivots. The green circles indicate where the center pivots are. We disregarded differentiating between partial and full center pivots because we wanted to focus on the spatial aspect of where the center pivots are instead.

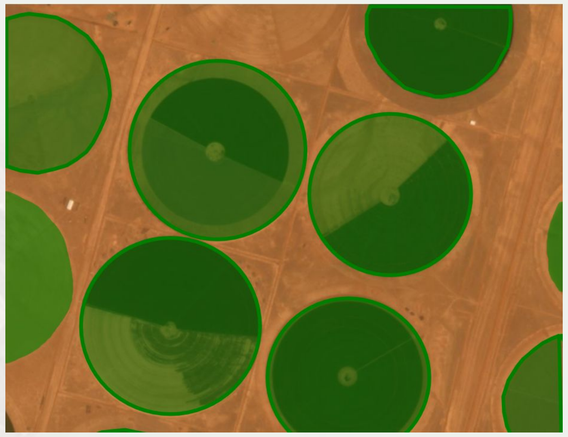

Figure 2: Before and after photos of the binary masking process. The image on the left is the original image pulled from Planet Labs and the image on the right is the masked image produced from the labeling process that contains 0s for areas that don't have center pivots and 1s for areas that have center pivots.

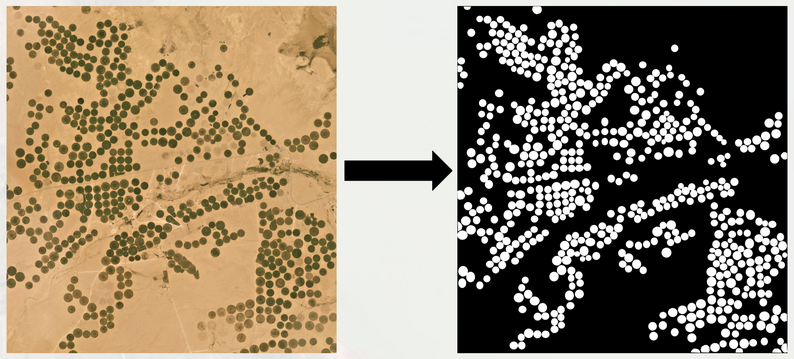

Figure 3: Before and after images of running the pulled satellite image through the U-Net model. The image on the right shows most of the center pivots identified accurately with some imperfections and incomplete circles.

Data Pipeline

1. Specify AOI and pull GEOJSON coordinates from geojson.io
2. Download every monthly image quad that is partially or completely within AOI
3. Composite image quads and crop to fit the exact GEOJSON coordinates
4. Annotate cropped image using our labeling interface, LabelStudio, and export annotations in JSON format (**Figure 1.**)
5. Convert the labels into a binary mask in Python (**Figure 2.**)
6. Stack the raw image and the binary mask, and then use a sliding window function to divide it into smaller image-label pairs
7. Augment data by rotating each image chip by 90, 180, and 270 degrees and by mirroring each rotated chip
8. Save dataset for model training and testing

Results

- **Dataset size:** The resulting dataset will be a very large size due to the TIF format and augmentation. The augmented dataset will be 12 times larger than the raw dataset. For example, a single AOI produced 662 images and label pairs, and after augmentation it became 7944. The size was over 15 GB for a single AOI after augmentation.
- **Documentation site:** We are in the process of documenting the process of setting up the necessary infrastructure (setting up Label Studio on a server and utilizing PlanetLabs API) as well as the data augmentation pipeline we implemented in creating the training dataset.
- **Radiant Earth submission:** We aim to upload our completed training dataset on to Radiant Earth so future projects may utilize high resolution images of center pivot irrigation systems.
- **GitHub Repository:** All our code and notebooks are available through the documentation QR code.

Conclusions

Potential future work

- To further the performance of the model, we could expand towards detecting active vs inactive pivots as opposed to only being able to detect the location of center pivots. Several agricultural regions also include partial pivots, which could be classified as well.
- We would also like to finish training the model using our training dataset and examine the accuracy using evaluation metrics.
- Once the model is complete, we can begin to analyze how center-pivot-irrigated plots have changed over time.

References

QR code to the paper we used for transfer learning

QR code to our documentation site