Deep Learning for Rare Energy Infrastructures in Satellite Imagery

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Duke ENERGY INITIATIVE

Lack of Training Data: Obstacle for Rare Objects

- Deep neural networks require **large amount of training samples**
- Many energy infrastructures are "**rare**", which makes it difficult to acquire enough training data

Power Plants

Wind Turbines

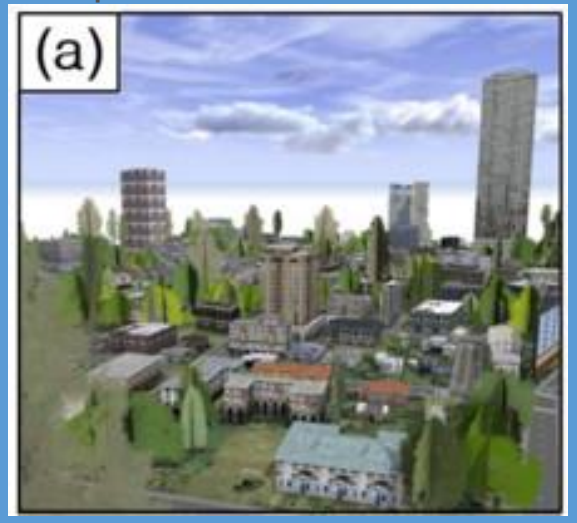
Oil Tanks

CityEngine: Create Synthetic Images

1. Virtual World Creation -- **CityEngine**

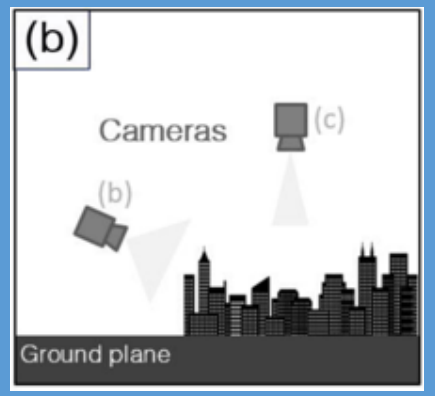
Virtual world generation

- Import 3D models
- Randomize size and placement

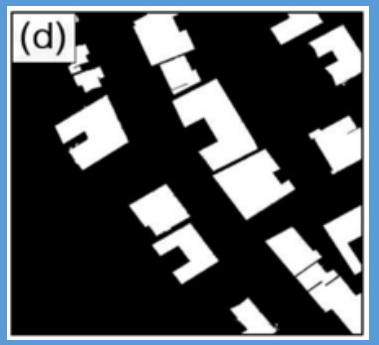


2. Synthetic Overhead Imagery Generation

Capture imagery



Output



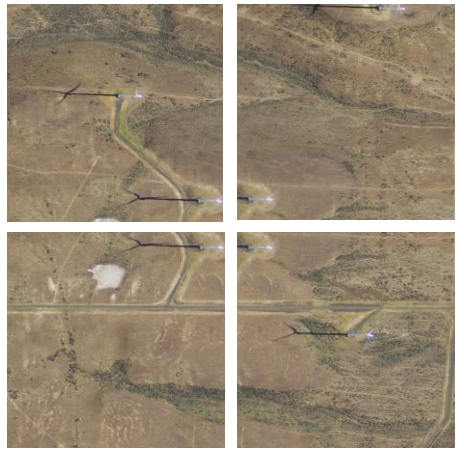
Research Steps

1. Create and process a real dataset to train our model as a baseline

Real Satellite Imagery

create labels and preprocess

Real Dataset



train model

Baseline Results

Synthetic Dataset

Imported 3D Energy Infrastructure Models

CityEngine +

Combine data & train model

Results With Synthetic Data

2. Create synthetic data using CityEngine and online 3D models of energy infrastructure

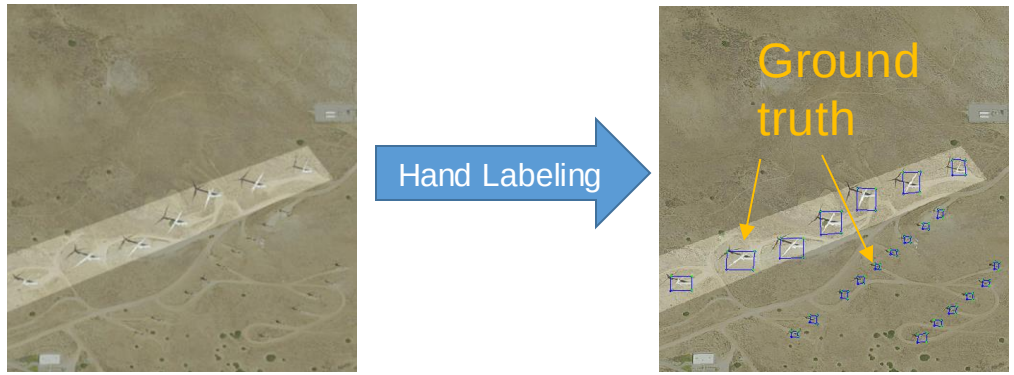
3. Train our network with a dataset supplemented by our synthetic data and compare with our baseline

Looking at our Data

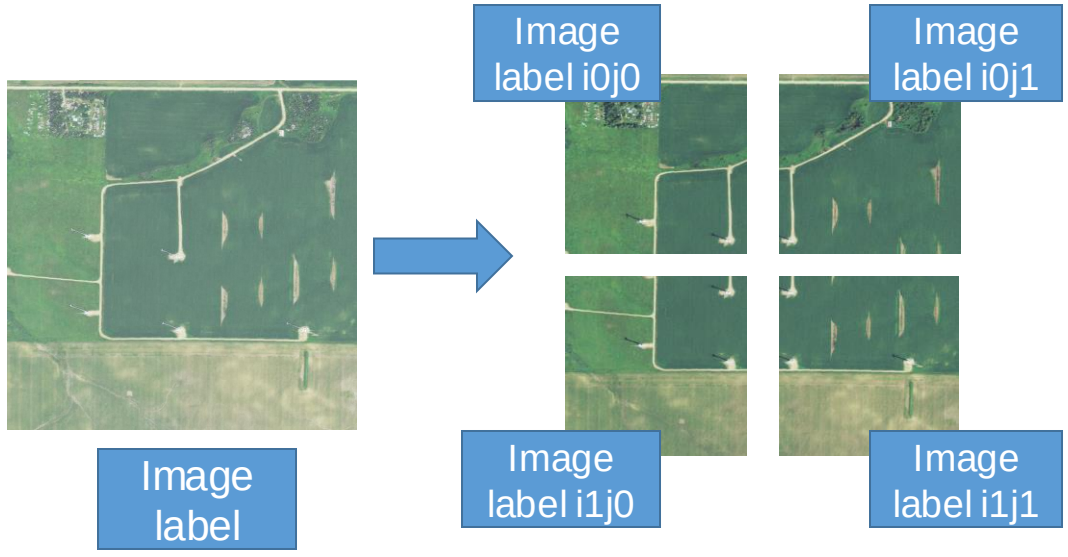
- Our dataset is a set of satellite imagery containing power plants
- We focus specifically on images containing **wind turbines**

Data Preprocessing

- Labeled and localized each turbine
  - Labels are used as ground truths that can be compared with the model's predictions to determine performance



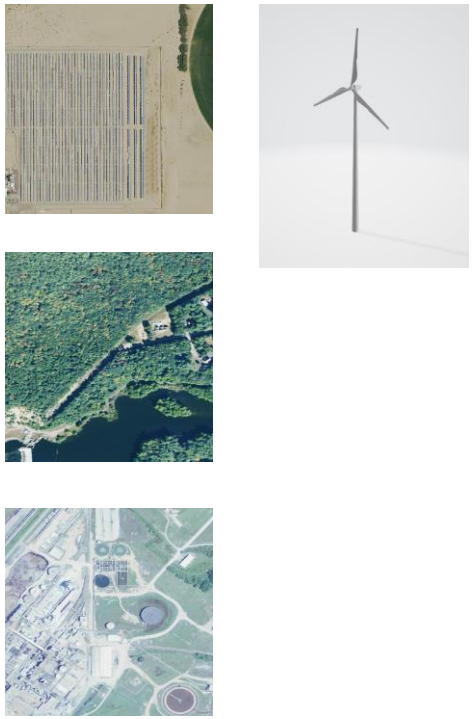
- Raw satellite images split into patches
- Adapt labels for each patch



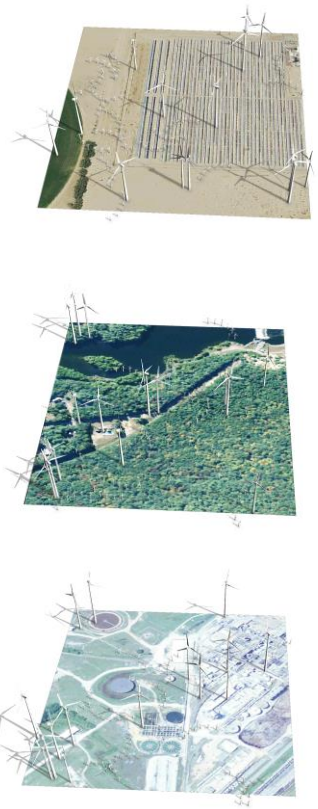
Creating Synthetic Data

- Generated models on top of images that did not contain wind turbines
- Used a script to generate new images and models randomly and then change the camera position and take photos of the scene

List of images + models

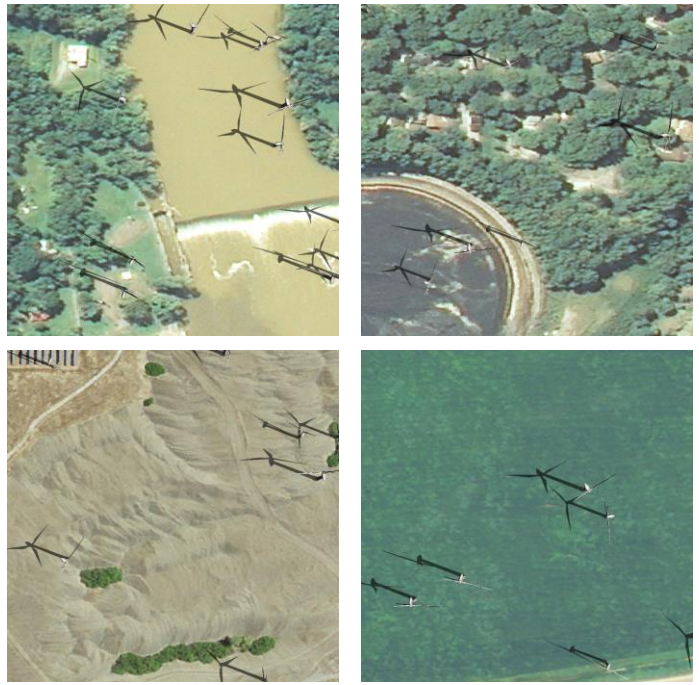


random generation



moving camera

Overhead images



Experimental Setup

Training Dataset A

- 1239 real images of wind turbines

Training Dataset B

- 1239 real images of wind turbines
- **441 synthetic images**

Testing Data

- 661 real images

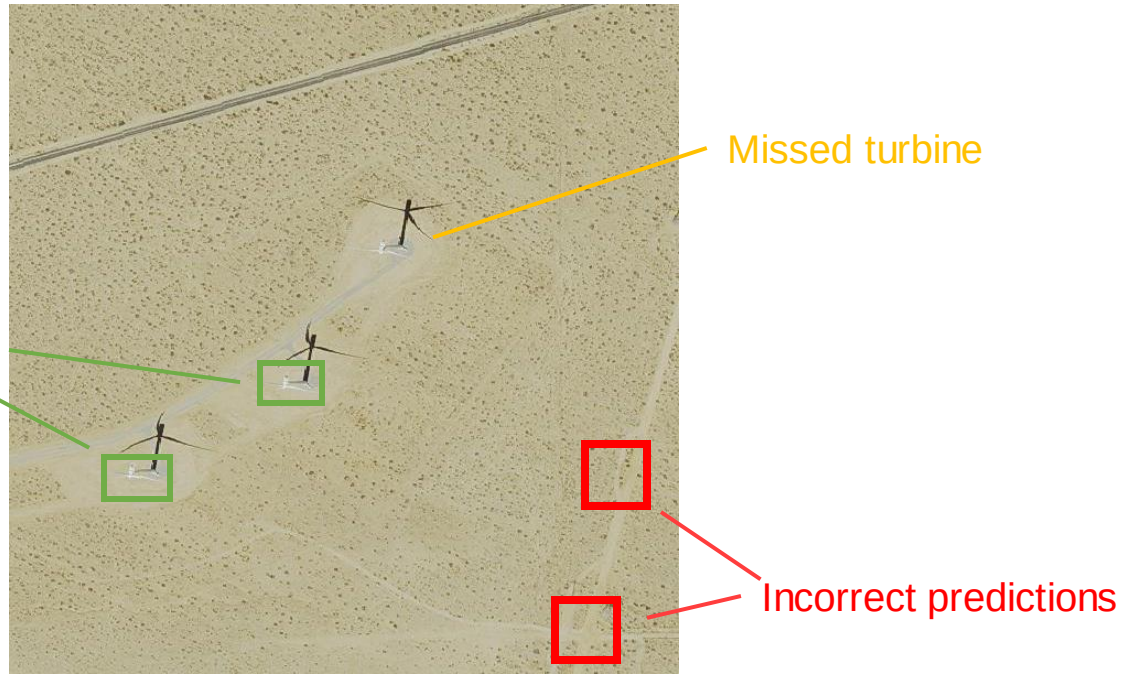
Results with real training images

Results with real + syn. training images

Data is split between training and testing randomly

Performance Metrics

- **Precision** and **Recall**
- Prioritize recall
  - Easier to remove misclassified turbines than to find undetected wind turbines



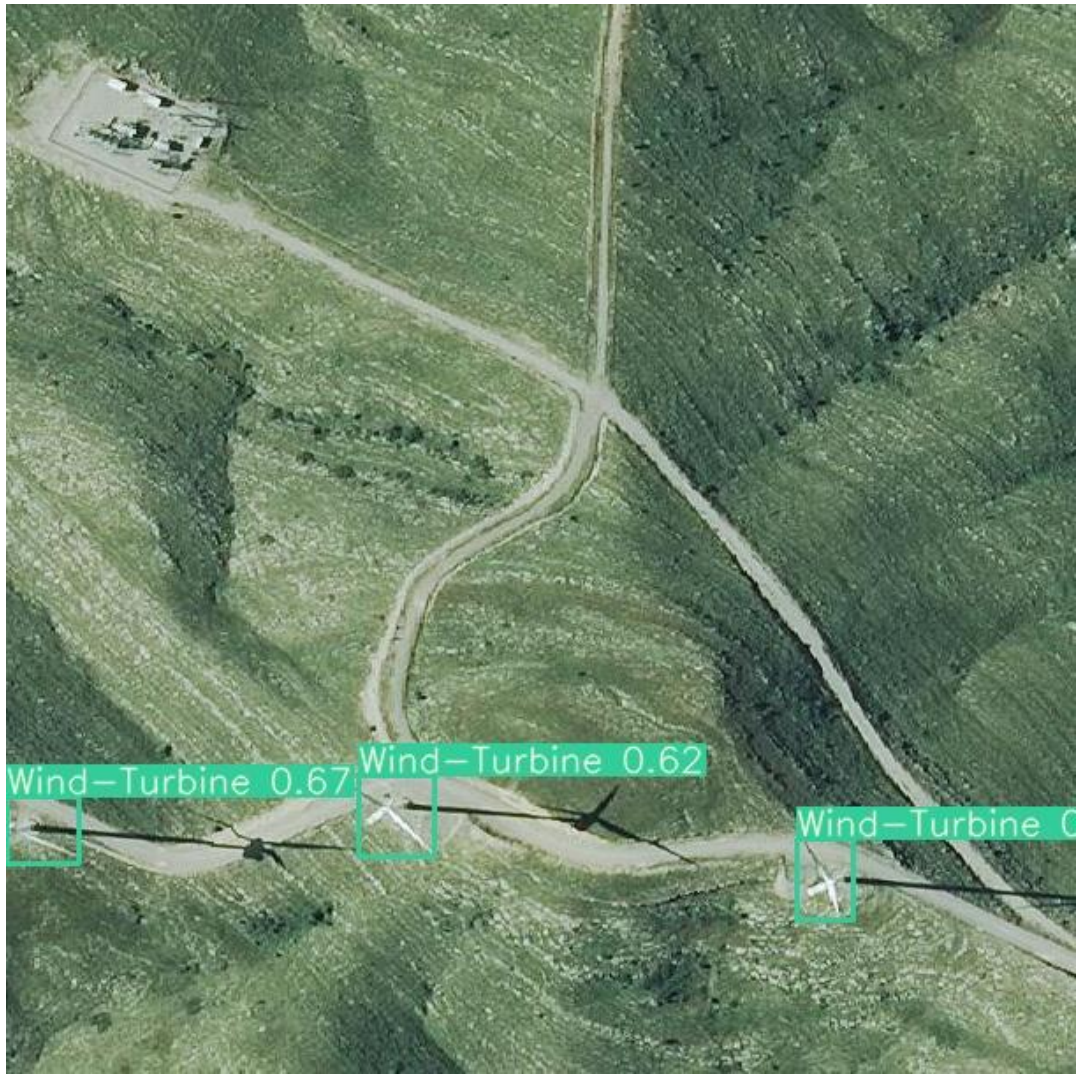
Precision = 2/4

Recall = 2/3

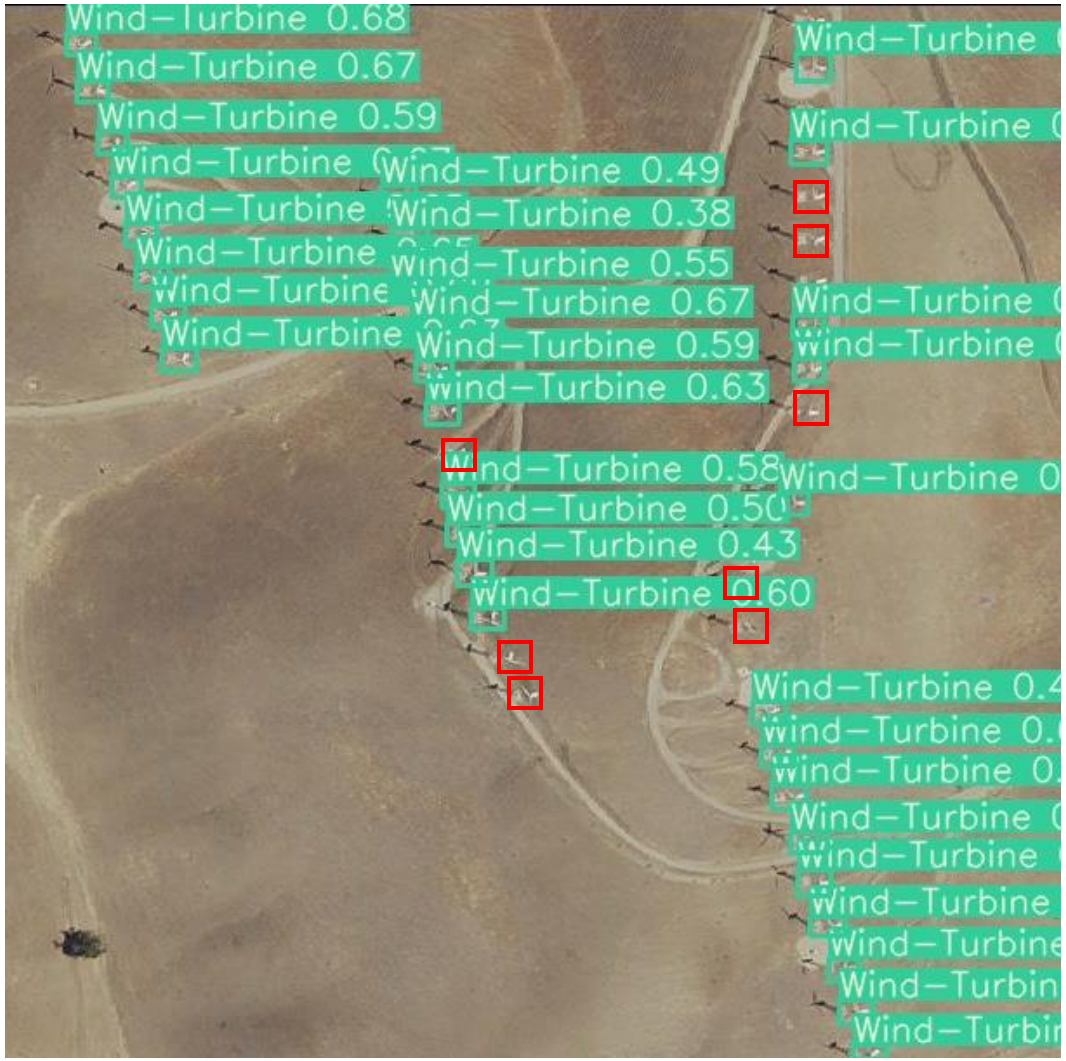
Adding Synthetic Data Improves Performance

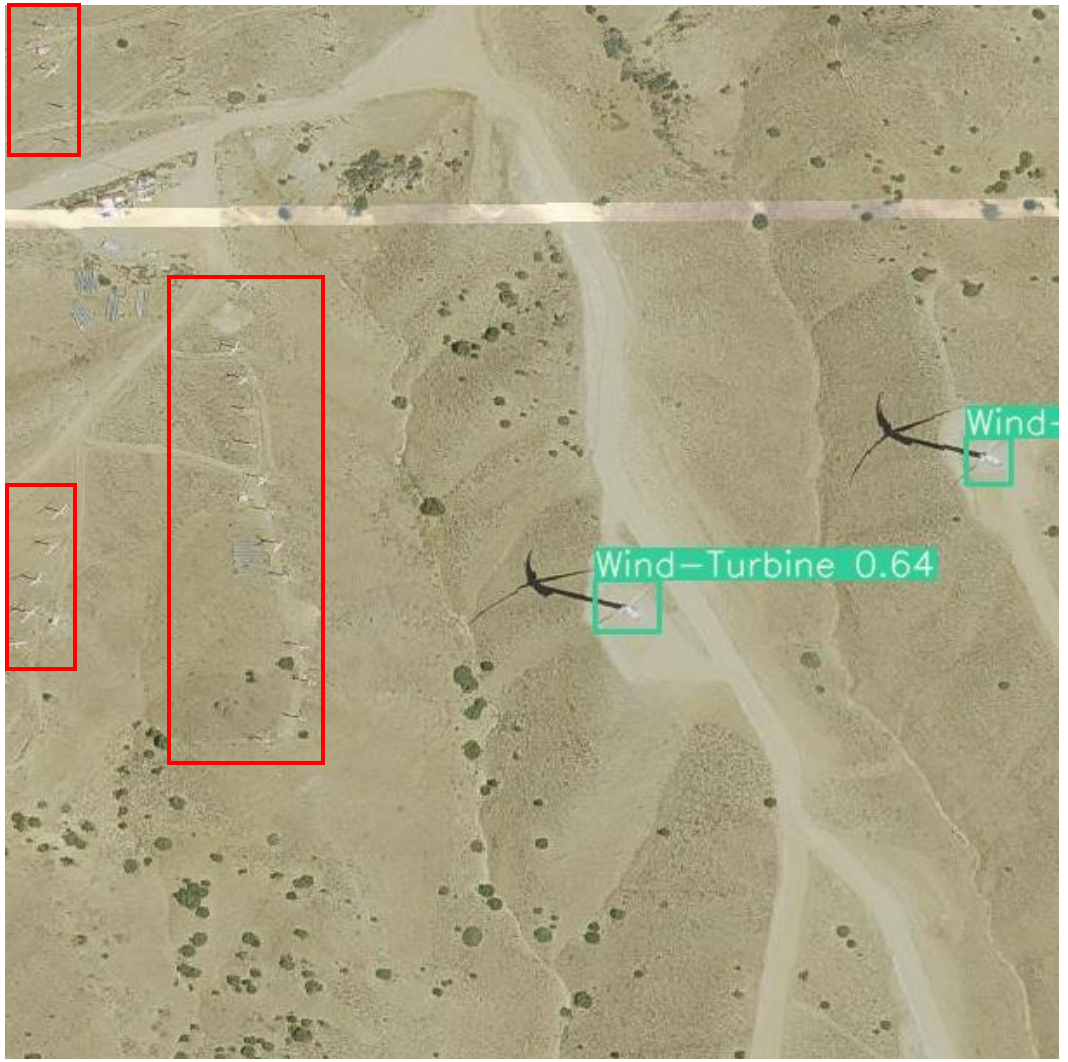
Training Data	Testing Data	Precision	Recall
Real	Real	0.813	0.825
Real + Synthetic	Real	**0.831***	0.827

Performs well on large wind turbines



Inconsistent on small wind turbines





Future Work

- Make synthetic imagery **more representative** of the real imagery
- Observe performance as the **amount** of synthetic data is varied
- Apply this model on a **large scale**
- Apply these techniques to detect **other types of energy infrastructure**

Thank You for Listening

- Project Website: https://dataplus-2020.github.io/
- Project GitHub Repository: https://github.com/dataplus-2020/yolov3_wnd_code
- Synthetic Dataset: https://figshare.com/projects/Object_Detection_Dataset_for_Overhead_Images_of_Wind_Turbines/86861
- Energy Data Analytics Lab: https://energy.duke.edu/research/energy-data