Satellite image segmentation for solar panel placement planning

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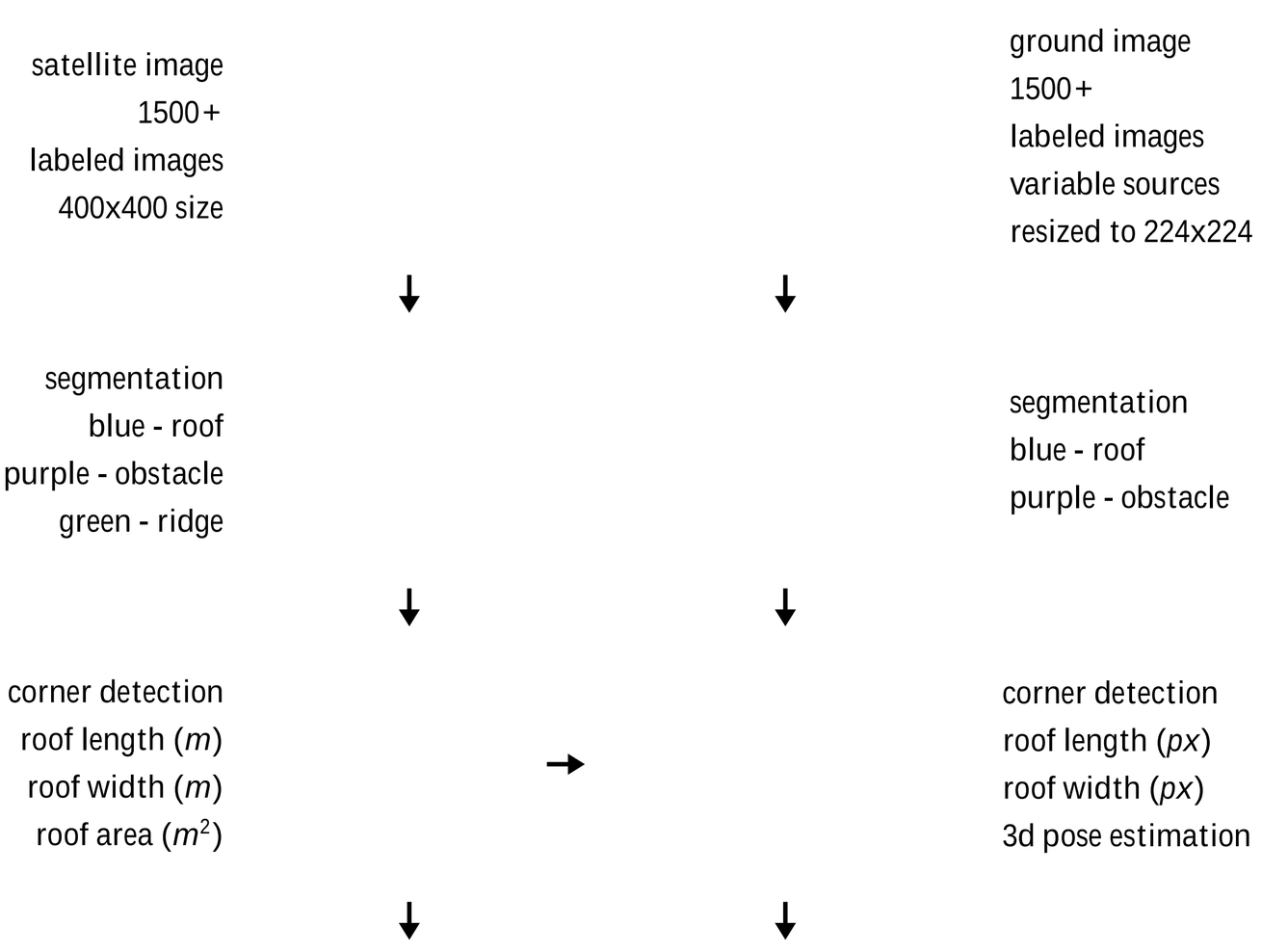
Project Goals

- Estimate the number of solar panels that can be fit on a roof
- Detect small objects ($< 1m^2$) with high confidence in satellite data
- Identify roof components:
  - roof sides
  - obstacles
  - ridges
  - dormers
- Measure the roof dimensions:
  - length
  - slope
  - width
  - area
- Merge satellite data information with user generated images
- Infer 3d information from 2d images

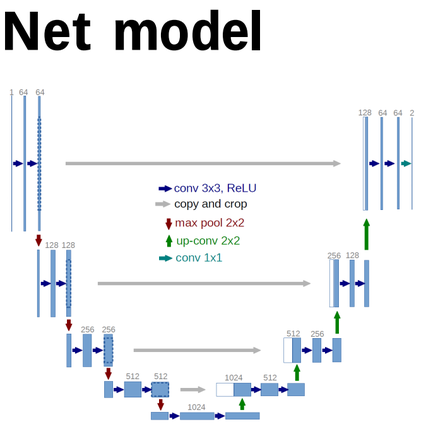
Processing Pipeline



Satellite Images Segmentation

- Challenges:
  - poor contrast
  - low resolution
  - image variability
  - hidden parts
  - connected roofs
  - small obstacles
- Solution:

U-Net model



Data augmentation

- flips and rotations
- intensity scaling
- Gaussian noise

Loss function

dice coe□cient: $_{\text{dice}}$

pixel weighting: $\tilde{w}_{ij}$

class weighting: w_k

$$_{\text{dice}}(\hat{Y}, Y) = 1 - \frac{1}{K} \sum_{k=1}^{K} \frac{2|\hat{Y}_{\cdot\cdot k} \quad Y_{\cdot\cdot k}|}{|\hat{Y}_{\cdot\cdot k}| + |Y_{\cdot\cdot k}|}$$

$$\tilde{w}_{ij} = w_0 \exp \quad -\frac{(c_1(i,j) + c_2(i,j))^2}{2\sigma^2}$$

$$_{\text{wcce pw}}(\hat{Y}, Y) = -\frac{1}{K} \sum_{i,j,k=1}^{d_1, d_2, K} (w_k + \tilde{w}_{ij}) Y_{ijk} \log p_{ijk}$$

$$_{\text{wcce}}(\hat{Y}, Y) = -\frac{1}{K} \sum_{i,j,k=1}^{d_1, d_2, K} w_k Y_{ijk} \log p_{ijk}$$

$$_{\text{wmse}}(\hat{Y}, Y) = \frac{1}{K} \sum_{i,j,k}^{d_1, d_2, K} \tilde{w}_{ij} (\hat{Y}_{ijk} - Y_{ijk})^2$$

$$_{\text{dice pw}}(\hat{Y}, Y) = \quad _{\text{dice}}(\hat{Y}, Y) + \quad _{\text{wmse}}(\hat{Y}, Y)$$

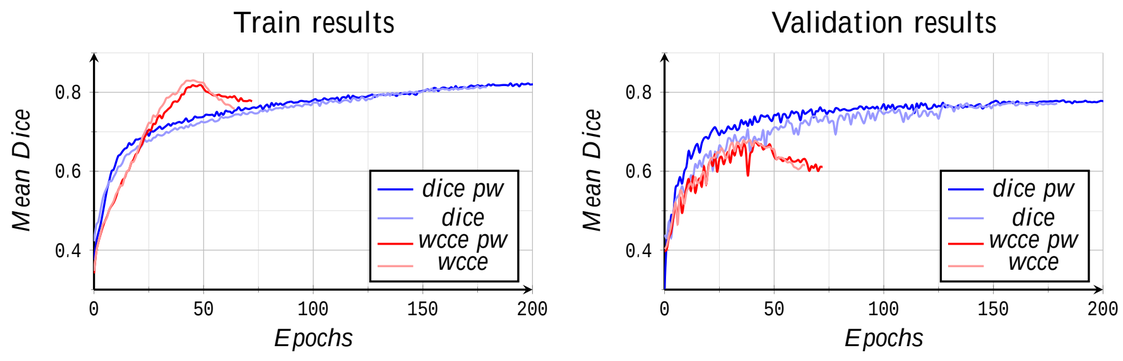
Hyperparameters

learning rate: 10^{-3}

batch size: 8

activation: sigmoid

Results



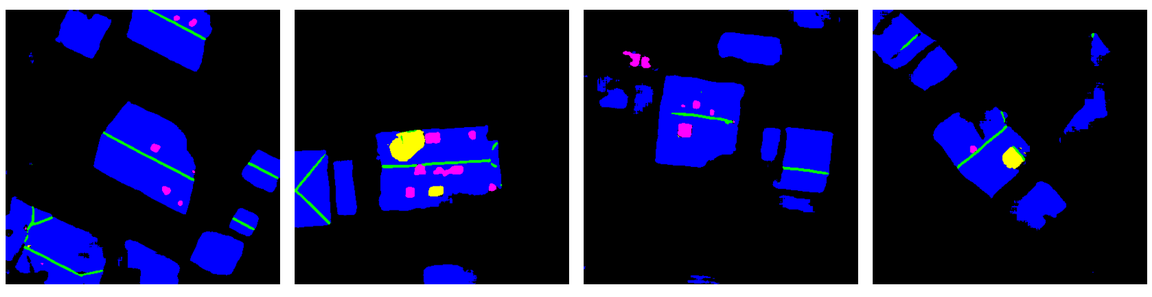
- Mean dice obtained for the roof structures using the weighted categorical cross-entropy (wcce) and the dice loss, with and without pixel weighting (pw) on test data:

	wcce		dice	
	no pw	pw	no pw	pw
Roof	0.66	0.66	0.78	0.80
Ridge	0.26	0.30	0.42	0.43
Obstacles	0.34	0.38	0.52	0.51
Dormer	0.27	0.50	0.64	0.68
Ground	0.94	0.92	0.96	0.96

Original image

Dice loss

Dice loss + pixel weighting



Take Home

- Deep learning, namely the U-Net model, reliably detects roofs and small objects on satellite data
- The dice loss with pixel weighting is superior to the common used categorical cross-entropy loss
- Satellite data can be matched with ground imagery allowing 3d information to be inferred