IOWA STATE UNIVERSITY
Center for Survey Statistics and Methodology

Charles Labuzzetta, Statistics PhD Student
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Finding Iowa's Grassed Waterways via Deep Neural Networks

Abstract

The Iowa BMP Mapping Project[1] has constructed a GIS catalogue of conservation practices established on farmland through review of aerial imagery from 2007 - 2010. Using this extensive dataset, we have been exploring the feasibility of using convolutional neural networks (CNN) to automate the process of image segmentation for one such conservation practice: grassed waterways. Early season color infrared imagery and LIDAR products[2] are useful sources of data for recognizing grassed waterways. A neural network such as the U-Net: A Convolutional Neural Network for Biomedical Image Segmentation introduced by Ronneberger, et. al. in 2015 can learn from training data and generate highly accurate image classifications. The U-Net for grassed waterway classification has been implemented on a small training dataset and validated with independent validation data. While the method achieves over 98% accuracy, the dice score for imbalanced data is a better metric for characterizing the model performance. On average, the dice score for each image is 0.625. The U-Net shows promise for image classification of grassed waterways via color infrared imagery and LIDAR products.

Methodology

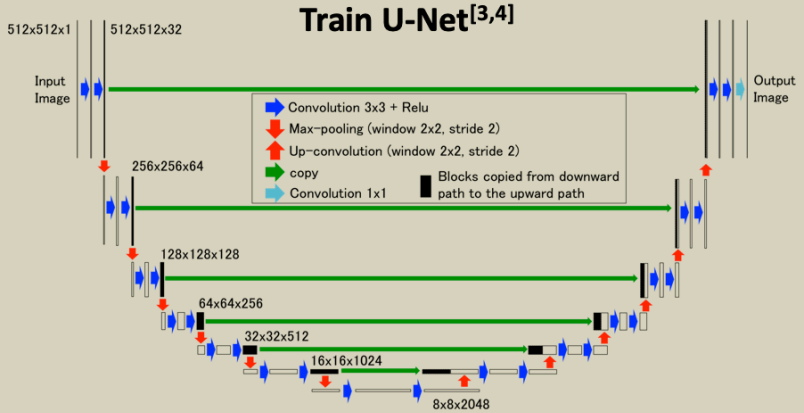
Training data

Gather Color Infrared and LIDAR (1 m spatial resolution) of 2000 sampled locations with grassed waterway.

Reference Data

Clip the BMP grassed waterway layer to each sampled region and generate reference raster.

Train U-Net[3,4]



Classify Validation Data

Use an independent sample of validation CIR and LIDAR images to calculate model accuracy.

Improve Model

Alter model architecture, add training imagery, add auxiliary imagery to improve model.

Methodology

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Gather Color Infrared and LIDAR (1 m spatial resolution) of 2000 sampled locations with grassed waterway.

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Clip the BMP grassed waterway layer to each sampled region and generate reference raster.

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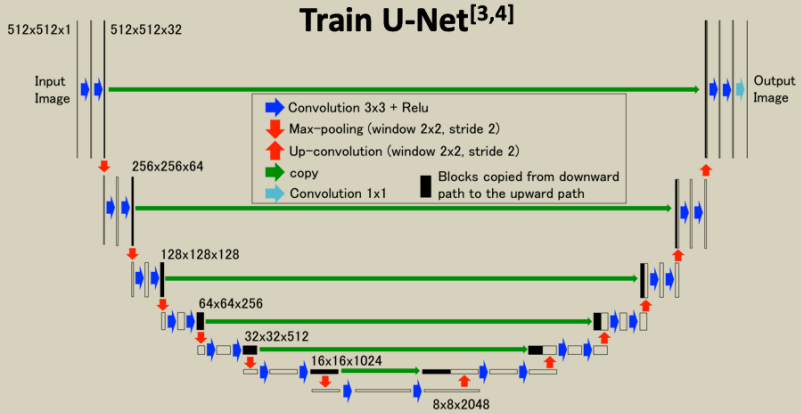

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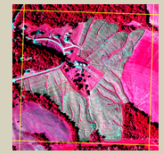

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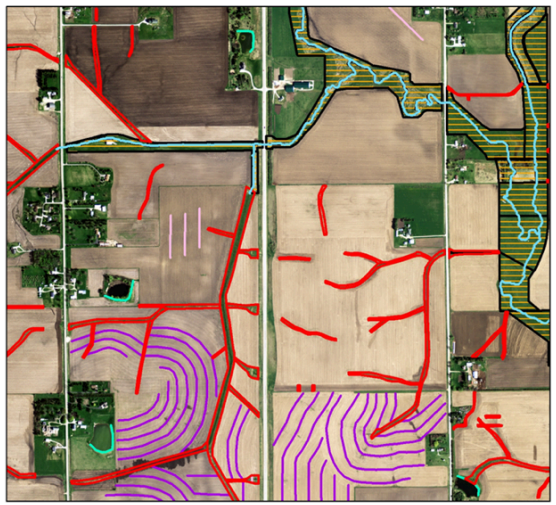
Iowa BMP Mapping Project



Digitized Conservation Practices in HUC 12 Watershed 0708050905 in Black Hawk County, Iowa

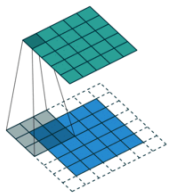
The Iowa BMP Mapping Project[1] is a GIS catalogue of Best Management Practices (BMP) installed on Iowa's agricultural land which contribute to meeting the requirements of the Nutrient Reduction Strategy[5]. This catalogue is a human evaluated record of BMP presence between the years of 2007 – 2010 including:

- Terraces
- Pond Dams
- Grassed Waterways
- Contour Strip Cropping
- Contour Buffer Strips
- WASCOBs

The Iowa BMP Mapping Project has required intense digitization labor for this limited temporal scope. **Our question:** Can convolutional neural networks automate the process for digitizing BMPs via Color Infrared and LIDAR DEMs?

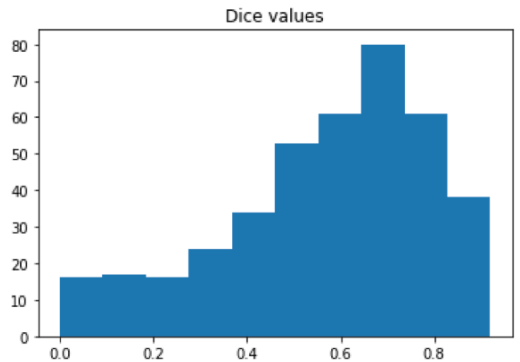
U-Net

The U-Net[3], originally developed for segmenting biological cells from background pixels in videos of cell movement, is a convolutional neural network which can also be used as a classification technique for remotely sensed imagery. The method is convolutional, implying that many hundreds of image transformations via filters are learned in order to recognize pixels which should be classified as grassed waterway. To the left[6], the blue input image is transformed by a single convolutional filter (gray matrix) into the green output image.

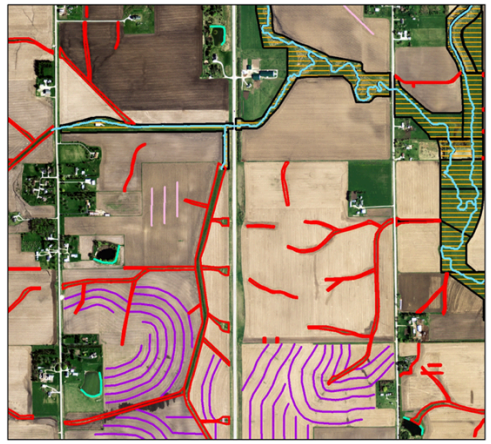


On our trial set of training data, the model predicted this distribution of 400 validation dice scores and the following mean metric values:

Accuracy:	0.98	Precision:	0.64
Dice:	0.61	Recall:	0.59



Iowa BMP Mapping Project



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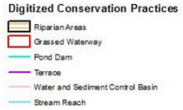

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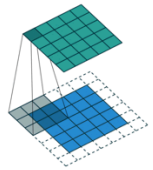

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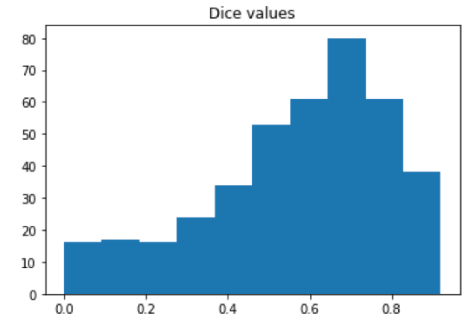
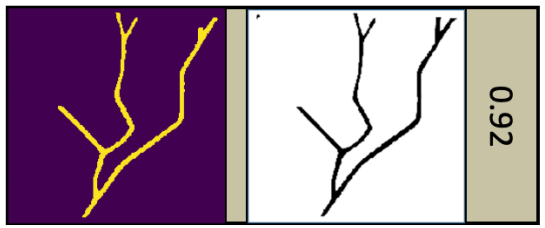
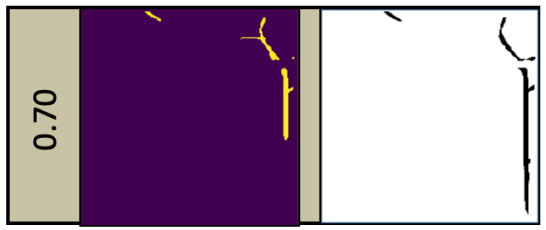
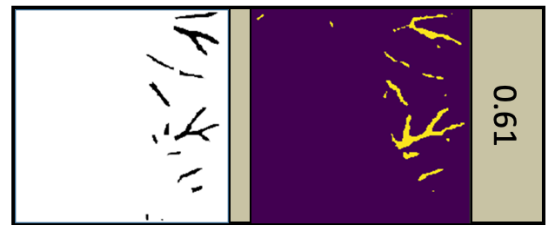


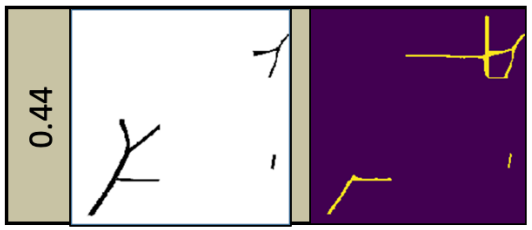
Model Performance

Accuracy of our model is high due to the high class imbalance of grassed waterway pixels compared to background pixels, implying that dice score is a better metric for evaluating model performance. Below, several case studies of the model classifications compared to the reference data are presented. It is expected that by increasing the sample size of the training data imagery, dice scores can be increased. Expanding the model architecture to accommodate extra color infrared imagery from different seasons may also improve model performance.



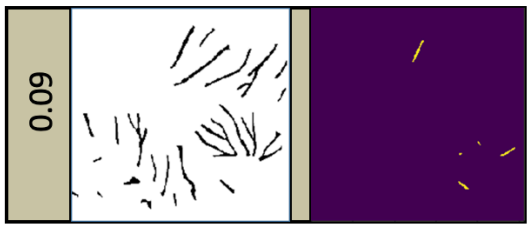






These images represent a variety of performance cases of the model. The model classifications in the purple and yellow images are compared to the black and white reference images as described by the key below. The highest dice scores are mostly affected by incorrect pixel classifications along the borders of the grassed waterways. In the worst cases, some grassed waterways are correctly classified but others are incorrectly added or left out completely.

Pred. Other Pred. GW Ref. Other Ref. GW



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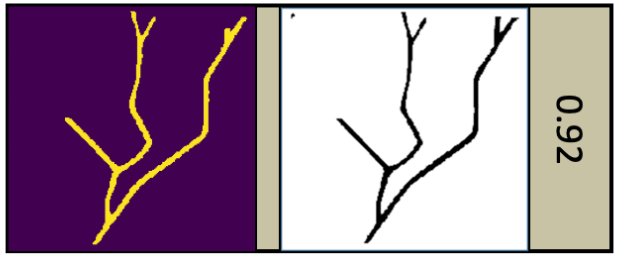

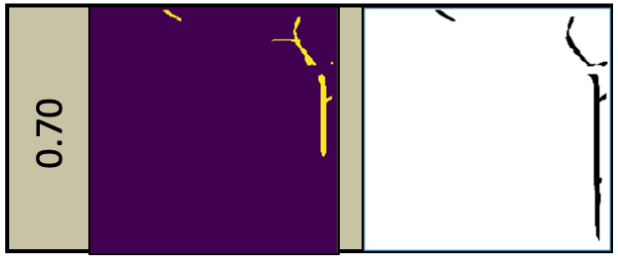

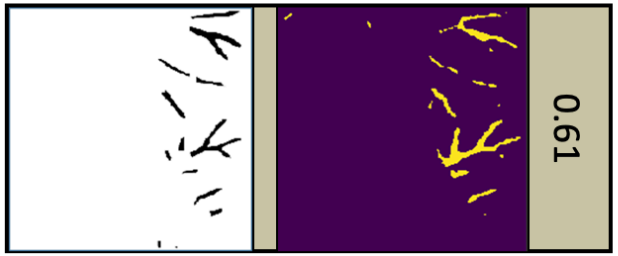

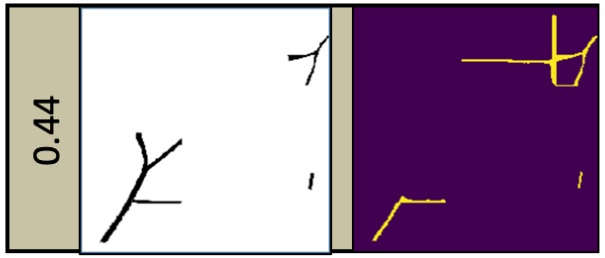

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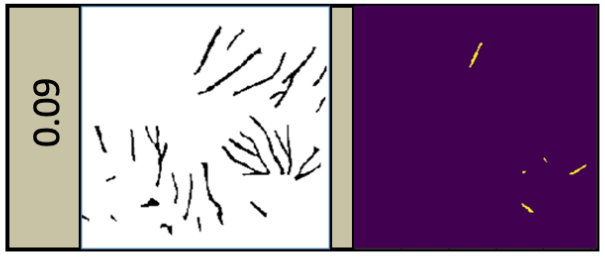

[1] Iowa State University, GIS Facility (2019) Iowa BMP Mapping Project.
[2] Iowa State University, GIS Facility (2019) Iowa Geographic Map Server.
[3] Ronneberger, et. al. (2015) U-Net: Convolutional Networks for Biomedical Image Segmentation.
[4] Qeffxmqkx, User (2019) Public domain image licensed for personal use via pngfly.com.
[5] Iowa Department of Agriculture and Land Stewardship (2013) Iowa Nutrient Reduction Strategy.
[6] Saha, Sumit (Dec. 15, 2018) A Comprehensive Guide to Convolutional Neural Networks – the ELI5 way.

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