Title: Deep learning for ecological image analysis: an example using Optical Character Recognition.

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Keywords:

# Abstract

# Introduction

To monitor biodiversity, ecologists and conservation managers need high quality temporal and spatial data on animal presence, movement, and behavior. The high costs, complex logistics, and significant expertise of human observation studies limit the ability to gather ecological data. Ecologists are increasingly turning towards greater automation to facilitate biodiversity monitoring. The decreased costs of image capture and growing library of analysis tools makes automated biodiversity monitoring closer than ever before.

A major obstacle to the growth of image-based ecological analysis is the efficiency of scoring and extracting information from images. Annotating images with metadata, such as time and species identity, requires significant time investment. The emerging field of computer vision can decrease the time for image annotation, increase consistency among annotators, as well as engage less experienced observers in biodiversity monitoring. Computer vision is a field of image-based computer science that uses image pixels to mimic human perception based on image characteristics, shape and sequence.

While computer vision has made incredible strides in a variety of fields, its growth in ecology has been slowed by a lack of access to high level algorithms. Computer vision publications are often short, terse, and filled with jargon. Given the potential lucrative opportunities for new algorithms, source code is rarely made available. While there have tremendous advances in artificial intelligence capability, ecologists have largely been left out of this revolution. The challenge lies in adapting existing tools to meet the time and budget limitations of practitioners.

The recent unveiling of the Google Cloud Machine learning platform could be a quantum leap in access to machine learning tools. Released in trial form in December 2016, google cloudML gives users access to a pre-trained image classification model and a robust web service to classify images using convolutional neural networks (CNNs). CNNs uses image features to classify objects into known categories (LeCun *et al.* 2015). Described colloquially as ‘deep learning’ CNNs do x,y,z by x,and y. For a full treatment of the technical details of CNN see X,Y,Z.

While there have been technical applications of deep learning for ecology (Chen *et al.* 2014; Gomez *et al.* 2016), it is the availability of highly sophisticated tools for average users which holds revolutionary potential. Rather than building a model from scratch for each applications, users can retrain pre-built models by teaching it new image classes. Known as transfer learning, this approach uses the strengths of the underlying architecture, but adds flexibility for specialized problems. This greatly reduces the time and expertise needed to implement image analysis solutions. While the number of classes for state of the art solution is increasing, off-the-shelf models are unlikely to contain all labels that might benefit ecologists. For example, a model, such as the Cloud Vision API tested here, may be able to differentiate a bear from a bird, but it cannot yet read the taxonomic resolution needed to contribute to ecological inventories. Through transfer learning, ecologists with ample labeled data of existing images can teach models new classes and develop specific solutions for their taxa and location.

## A sample problem: extracting metadata from wildlife images

In 2013, my colleagues and I began placing time-lapse cameras in the montane cloud forests of Ecuador to monitor hummingbird-plant interactions. Our goal was to replace traditional human observation with image-based tools to increase the extent of spatial and temporal sampling. Ecological networks, and plant-pollinator networks in particular, are chronically under-sampled, due to the rarity of many interacting partners and the seasonal pattern of flower phenology. By using cameras that turn on at 6am, turn off at 6pm, and take 1 photo per second, we can refine our understanding of the ecology of tropical communities and the co-evolution of plant-pollinator interactions. We currently have twenty cameras generating nearly 100 GB of video data per month, with plans of increasing to >50 cameras across multiple sites. The videos are screened using computer vision software to find important candidate motion events, which reduces the total number of reviewed frames by >90%. These candidate frames are then scored by a human to record species identity, the time, date, and behavior of individuals. Manually review of frames still is a large bottleneck in generating datasets, and limits the scalability of our approach.

Using cloudML my aim is to retrain the existing machine learning algorithm to identify the printed digits and characters in the image. I will compare the accuracy of this approach with using Google’s cloud vision API, which performs text detection, but has not been trained for my specific use case. Finally, I will compare these results to open-source software commonly used for digital character recognition. By evaluating the accuracy, obstacles and costs of each approach, I provide a first test of the efficacy of these tools for ecological image analysis.

# Methods

Our aim is test the performance of Google CloudML in extracting timestamp metadata from a set of 500 scored photos (Fig 1). This represents the first step in moving towards automated image analysis, and will provide a simple test case for the effectiveness and costs of this new service. Machine learning for optical character recognition (OCR) is a well-tested field of research and was a good choice for a first test of this new service.

## Building an machine learning model

To build a machine learning model, there needs to be a training dataset, and an evaluation dataset. These datasets contain labeled images with which we will retrain the existing neural network. The first step is to generate a dataset of known letters. To generate a training dataset, I developed a python script to identify the location of letters within the image, split letters based on their outline, and process the letters to increase size and clarity (Fig. 2). All images were captured using a Plotwatcher Pro camera (Day 6), and therefore had the camera ID, date, and time in same position. I then manually coded the known letters based on existing image metadata that had been collected earlier in the project. I split the dataset into 85% training and 15% testing data, with a maximum number of 300 letters per class. From my existing stock of images I was able to recover digits 0-9, semicolon, forward slash, and the letters (A, C , E , F , H , L , M , O , P , R , T , W , Y). The remaining letters were not found in available images, and were not included as potential classes.

I retrained the InceptionV3 model provided by Google’s using the python package Tensorflow, following online resources. All source code can be found at the git repository online (). I ran the retraining for X steps, based on X, and Y.

As a standard of comparison, I compared the performance of a re-trained Inception model on Google CloudML with tesseract, a highly regarded open-source tool for OCR. Tesseract is itself a machine learning tool developed at google, and is designed for transcribing text from visual images.

# Results

# Discussion

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Figure 1. A sample image of a female violet-tailed sylph (*Aglaiocercus coelestis*) visiting a *Guzmania jaramilloi*. At the bottom of each image is a camera ID, date and time stamp.