CIS 3715 Final Project Report

Using satellite imagery to train a model for identifying the type of landmarks.

Leomar Durán

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Revision History

Table 1: Revision history

Revision #	Author	Revision date	Comments
2.1.0	Leomar Durán	2022-04-10t23:49	finished progress report I
2.0.0	Leomar Durán	2022-04-06t12:30	lessons learned from past work, started progress report
1.14.0	Leomar Durán	2022-04-06t04:32	initial time line
1.13.0	Leomar Durán	2022-04-06t02:40	issues with convolutional neural networks
1.12.0	Leomar Durán	2022-04-05t23:10	added issue of over/underfitting to related works
1.11.0	Leomar Durán	2022-04-05t17:40	added issue of computer vision to related works
1.10.0	Leomar Durán	2022-03-25t23:57	design and implementation challenges, started anticipated project outcomes and impacts
1.9.0	Leomar Durán	2022-03-25t23:46	data science fundamentals, project objective and constraints
1.8.0	Leomar Durán	2022-03-25t22:31	finished overview of problem, flush level 1 lists
1.7.0	Leomar Durán	2022-03-25t22:19	moved description of dataset to proposed work
1.6.0	Leomar Durán	2022-03-25t22:16	added revision history
1.5.0	Leomar Durán	2022-03-25t21:47	added more about the dataset, grammatical fixes
1.4.0	Leomar Durán	2022-03-25t02:45	started bibliograph, problem statement
1.3.0	Leomar Durán	2022-03-25t02:10	motivation, flushed heading numbers into margin
1.2.0	Leomar Durán	2022-03-25t02:05	sections, title, students
1.1.0	Leomar Durán	2022-03-25t01:55	page specifications
1.0.0	Leomar Durán	2022-03-25t01:51	starting proposal

Part I

Progress Report II

1 What has been done

The sampling is working now. I can now load the datasets, so it will be possible to work with the sampled datasets now.

2 What has not been done

I have not started working on the preprocessing or the model yet.

3 What will be done during the following week.

I will do my best to get preprocessing out of the way and do some basic model training and testing. It will be an iterative process so I can choose the best minimal model.

Part II

Final Project Proposal

Project title and student names

- **Project title:** Using satellite imagery to train a model for identifying the type of landmarks.
- **Student names** (1)
  - Leomar Durán

1 Introduction section

1.1 Motivation

The sciences of geomatics and land surveying interest me as hobbies. I really enjoy the idea of collecting data about the terrain, whether it be rural or urban, and working with that data to find solutions to problems or even just for fun.

1.2 The Problem

Overview

An image of a terrain is given to a computer which will make a decision on the fly based on the type of terrain. We will train a model that will be used by the computer to identify this terrain.

This sort of decision might be involved in deciding if the terrain would be appropriate for developing a building thereon. A preliminary sweep by a machine may save on costs of having an engineer waste time looking for land to develop. Another example of making this decision may be helpful for automatic landing software that will be used to safely land aircraft on stable terrain. A third example is that combined with time series data, we can predict different types of natural weather-related phenomena, such as draughts, floods and earthquakes.

Data science fundamentals

This problem involves multi-class classification. We will classify the terrain according to features such as whether the area is urban, densely forested, mountainous, or contains water for 4 disjoint classes.

We will evaluate the results using accuracy, recall, precision and the F1 score.

Project objective and constraints

For this project, we hope to train a model to learn different 4 disjoint classes of terrain, and then classify a test sample.

The algorithm that we pick has to deal well with the curse of dimensionality, as there will be $(28 \times 28)\text{px/examples} \times 4\,\text{channels/px} = 3136\,\text{channels/examples}$.

Ideally the solution would also perform well for multiple clases, but this is less of an issue than dimensionality.

1.3 Related works

One of the historical approaches to this problem is that by Basu, Ganguly, Mukhopadhyay, *et al.* [1] themselves, who used a combination of computer vision and neural networks.

Computer vision: Use machine learning and neural networks to teach computers to see [2] compares computer vision with human sight as well as artificial intelligence, making the analogy that computer vision is to seeing as artificial intelligence is to thinking.

However, *Computer vision: Use machine learning and neural networks to teach computers to see* [2] also clarifies the disadvantages of computer vision to traditional machine learning models. Specifically, "[c]omputer vision needs lots of data. It runs analyses of data over and over until it discerns distinctions and ultimately recognize images." That is to say that computer vision has high time and spatial complexity. Because of the amounts of data required, it will require much storage, and the same compounded by the number of iterations that must be performed, training a computer vision model will require much more time. IBM explains that the scale needed for time and storage is such that few organizations have the necessary infrastructure, and as a result, many use a service such as IBM's to perform computer vision [2].

When it comes to neural networks, common issues include overfitting and underfitting[3][4]. Overfitting is when a model is too specific to the training data. As a result when the model is tested against the testing data, small differences can create large errors compared to the expected output[5]. Underfitting results from a model that is too simple and results in high errors in comparison to the expected results for both testing and training data[3]. In order to avoid both, Lawrence and Giles [4] suggests the more complex technique of backpropagation.

Rolf, Proctor, Carleton, *et al.* [6] provides another method of training a model on satellite data. Specifically, they used a hybrid system. First, there is a 18-layer convolutional neural network[7]. However, rather than producing a single output, it produces 2^9 features. There is a second convolutional neural network with a ReLu activation function, which produces 2^{13} features[6]. The values are then concatenated and placed in a linear regression with a ridge regularization function[6].

Sharma [8] explains the two main issues with the convolutional neural network, two of which form the basis of this model. One issue named are that the convolutional neural network is sensitive to variation in images, such as different in phase of the object being imaged, differences in lighting, and differences in positioning. The other issue is that convolutional neural networks are sensitive to even low levels of additive Gaussian white noise.

To satisfy what we have learned from past systems, we will work from the bottom up using a simpler system that will not overfit, iterating until we find the lowest system that will have good performance. This will also solve the issue of noise because this problem is complicated by overfitting. As for position and phase of the image, this is a much different problem to tackle and outside of the scope of this project. However, if the image were more more regular and you could expect a guideline, it could be used to properly orient the image using a rotation matrix.

2 Proposed work

We are given The SAT-4 airborne dataset[1]. This data is hosted by the Louisiana State University's Division of Computer Science and Engineering[1] and can be downloaded directly from the Google Drive[2] along with the SAT-6 airborne dataset, or by itself from Kaggle[3].

The dataset consists of 400,000 example tiles taken from satellite imagery originally from the National Agriculture Imagery Program (NAIP) dataset. Each example has features representing the pixels of a (28×28)px image multiplied by the channels for red, green, blue and near infrared (NIR). According to Basu, Ganguly, Mukhopadhyay, *et al.* [1], these tiles represent "different landscapes

[1] <http://csc.lsu.edu/~saikat/deepsat/>
[2] <https://drive.google.com/u/0/uc?export=download&confirm=sWVM&id=0B0Fef71_vt3PUkZ4YVZ5WWNvZWs>
[3] <https://www.kaggle.com/datasets/crawford/deepsat-sat4>

like rural areas, urban areas, densely forested, mountainous terrain, small to large water bodies", so these as a disjoint set of landscapes would make for appropriate labels.

Our proposed solution is a multi-class logistic regression.

2.1 Design and implementation challenges

A challenge to this solution is the size of the dataset. Because of its size (about 3 Gbyte), we expect long processing times. One possible solution to this challenge may be to reduce the datasize from 400,000 to a more managable number such as 20,000.

Another issue that we will run into is deciding the best way to split the classes for the multi-class classification.

2.2 Anticipated project outcomes and impacts

An anticipated outcome is a model that can identify the types of terrains accurately from the given dataset.

3 Timeline

Table 2: Time line

Objective	Due Date
data set research	2022-03-24
initial proposal	2022-03-25
proposal revising	2022-04-06
initial data understanding, visualization	2022-04-06
progress report I revising	2022-04-06
pre-processing of data	2022-04-08
progress report II	2022-04-09
experimenting with logistic regression hyper parameters	2022-04-15
lightning talks	2022-04-19
revising presentation of results	2022-04-22
working on final report	2022-04-23
"	2022-04-24

4 References

[1] S. Basu, S. Ganguly, S. Mukhopadhyay, R. Dibiano, M. Karki, and R. Nemani. "Deepsat - a learning framework for satellite imagery, acm sigspatial 2015." (2015).

[2] "Computer vision: Use machine learning and neural networks to teach computers to see." (2020), [Online]. Available: `https://www.ibm.com/topics/computer-vision`.

[3] S. Vignesh, "Overfitting in deep neural networks & how to prevent it," *Medium, Analytics Vidhya*, 2020. [Online]. Available: `https://medium.com/analytics-vidhya/the-perfect-fit-for-a-dnn-596954c9ea39`.

[4] S. Lawrence and C. L. Giles, "Overfitting and neural networks: Conjugate gradient and backpropagation," *IEEE Xplore*, 2005. [Online]. Available: `https://ieeexplore.ieee.org/document/857823`.

[5] H. Gao, "Lecture 7: Linear regression," *Temple University, CIS 3715/Principles of Data Science*, 2022.

[6] E. Rolf, J. Proctor, T. Carleton, *et al.*, "A generalizable and accessible approach to machine learning with global satellite imagery," *Nature Communications*, 2021. [Online]. Available: `https://www.nature.com/articles/s41467-021-24638-z.pdf`.

[7] "Resnet18: Resnet-18 convolutional neural network." (2018), [Online]. Available: `https://www.mathworks.com/help/deeplearning/ref/resnet18.html`.

[8] P. Sharma, "Disadvantages of cnn models," *OpenGenus IQ*, 2020. [Online]. Available: `https://iq.opengenus.org/disadvantages-of-cnn/`.

Part III

Progress Report I

1 What has been done

I have mostly been working on the sampling. Because of the limitations of my computer, I cannot load the entire dataset into memory and perform operations on it. As a result, I will instead sample both datasets into 20,000 examples before working with them.

My progress is available at my project repository.

2 What has not been done

I have not started working on the preprocessing or the model yet.

3 What will be done during the following week.

I will do my best to get preprocessing out of the way and do some basic model training and testing. It will be an iterative process so I can choose the best minimal model.