UNIVERSITY OF SCIENCE AND TECHNOLOGY OF HANOI
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Group Project

Plankton Classification Platform for Supporting Research Activities of Environmental Scientists

Report 2

Submitted by

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Abstract

In our daily life, plankton has an important role that we cannot deny it in ecosystem and human life. Because these tiny organisms are the one that is almost controlled the carbon cycle of the Earth. In food cycle, they play the key role of the sustainability as the producer, the primary food for other animals. Even some specific kinds of plankton can be used as medicine for some severe diseases such as cancer. However, even though plankton can cure cancer but for the time being human still not find the solve to it. Moreover, due to the climate change, the population of plankton varies significantly and with controlling. This will cause many problems in the end, such as red tide phenomenon, fish-quantity fall and even economical-relating problems. In this project, the plankton classification platform was built. There are two main part: model development and website development. The model part allows putting unlabeled plankton images to their type of plankton that they belong to. And the website part will provide environmentalists with a friendly web user interface to perform classification task resulted from the model. From the experimental test with a domain in our datasets, we have produces good results after many failed train data, we have the accuracy over 80%.

I. Introduction

Plankton is a diverse group of organisms that live in the oceans and cannot swim against the water current [1]. And they have an important role to ecosystem and human life that we cannot undeniable. The carbon cycle of the Earth is almost controlled by these tiny organisms. In order to study plankton's population that is imbalance nowadays because of the ecosystem changed. Underwater camera systems are used to capture microscopic, high–resolution images of plankton over large study areas. However, there are a huge amount of plankton images, it's raises a key question that how we can analyze the collected plankton images in order to assess the population and distribution of plankton species. A natural approach to this question is to manually classify collected plankton images for further human analysis This approach, however, is infeasible since it would be extremely time and cost consuming to manually classify millions of images [2].

Figure 1. An Image of Plankton

1. Context of Project

To overcome this problem, the project has two main goals:

(1) To develop a classification platform to automatically put new plankton images in their correct categories;

(2) To build a plankton website so that the environmental scientists can contribute plankton data for easier use of plankton images in research and education.

2. Main Question

When we were doing our project, there are a lot of questions that come up to us. However, there is a question that our team care most is "Is our website can automatically detect new kind of plankton and tag it to a group in gallery when people upload to website's data?"

This question come up when we very worry about what if the website can only detect the image from a type of plankton that we had put in the train model, when we are doing the project. Will it detect the new plankton or they will they the new plankton is just some kind of random image come up. We still thinking a about that problem for the time being. And not yet find the answer.

3. Aims and Objectives

- **Aims:**
    - This project is about making a website using knowledge that we learned in the university.
    - To develop teamwork skill with the use of tools like Github and Google Doc.
    - To learn process of making a project.
    - Build a groundwork that can be reused and expanded in the future.
    - Understand the basic background about machine learning and image classification.
    - Successfully build and develop a part of website that image can be upload to website data, and website can detect that image belong to which type of plankton.

- **Objectives:**
    - Apply image classification models for the case of big datasets.

- Apply image classification models to build plankton classification platform.
- Develop web user interface for environmentalist to use plankton classification platform and let people also can contribute plankton data for easier use of plankton images in research and study

II. Literature Review

Nowadays, there are many kinds of methods in the literature to classify plankton around the internet. One of them that we cannot discuss about is an automated platform for classifying and monitoring phytoplankton that using scanning flow cytometer. This cytometer was designed to analyze the natural properties of plankton. For example, the cytometer is capable of analyzing from small to large planktonic particles (from 1 to 700 μm in diameter and a few mm in length) and relatively large water volumes. The platform manipulates and visualizes data using R programming language. The datasets also include original sampled volume, date, time, and depth at which particles were taken.

This platform was proposed by pomati et al, 2011 [3]. With the idea of a platform that it is able to extract very detail information of planktonic particles for further analysis is very interesting. However, if students or researchers want to have a large amount of plankton datasets for large-scale studies, the platform shows the limit in gaining high efficiency to classify the plankton. This is because the platform has not yet taken into account the advanced data analysis techniques to handle big datasets. So to solve the problem difficult use of plankton images for research and education, we come up with an idea that we create a website, an online plankton analysis system (PAS) for environmentalist to use plankton classification platform. Basically, the system is a web application allowing marine biologists to classify their plankton images using a web user interface. PAS provides the functions for experts to upload their images, process them, extract features, hand-label image, train classifiers, and use those classifiers to automatically label new images [4]. So that people can contribute plankton data in order to help other people want to research and study. And to make thing much easier than pomati et al, 2011 [3] platform by we apply the modern machine learning methods to our website, namely convolutional neural network, in order to gain high performance computing when analyzing large datasets.

III. Scientific Methods

From what we mentioned above that our motivation in this work is to build a classification platform to put new plankton images into their correct categories. In the following, we will present in detail the machine learning methods we use to perform this motivation.

1. Machine learning and image classification

According to Michalski et al, 2013 [5] machine learning is a field of study that provides computers with ability to learn from experience. To the detail, that we talked about that a computer program is said to learn from experience if it can teach itself to grow and change having new data. With the detail, we can tell that machine learning focuses on the development of computer algorithms for transforming data into appropriate action. For example, that make it easier to understand how the machine learning environment work. In the environment, there are available data, statistical models and computing power are simultaneously interacted with each other. As a result, from that, growth in data causes the need of additional computing power, which in turn spurs the development of statistical method for analyzing large datasets. This make it become a loop cycle of advancement allowing even larger and more interesting data to be collected.

Image classification refers to the task of classifying images into appropriate classes or categories that they belong to. In other word, we can say that image classification algorithms perform the press of putting unlabeled images into their class, type or categories that they belong to.

In the following, we will present our study on the machine learning models - convolutional neural network as the image classification models.

2. Image classification models - Convolutional Neural Network.

Convolutional Neural Networks (CNN) is a variant of multilayer perceptron (MLP) introduced by LeCun et al, 1998 [6] to overcome the weakness of MLP. To the detail, like we had mentioned above, it is wasteful to connect each neuron in a hidden layer to only a local region of the input layer. This connection is executed by using a convolution filter over the input layer and the hyper-parameter of such region is called the receptive field of the neuron. The convolution filters act as local filters over the input space and are well-suited to exploit the strong spatially local correlation in the natural images.

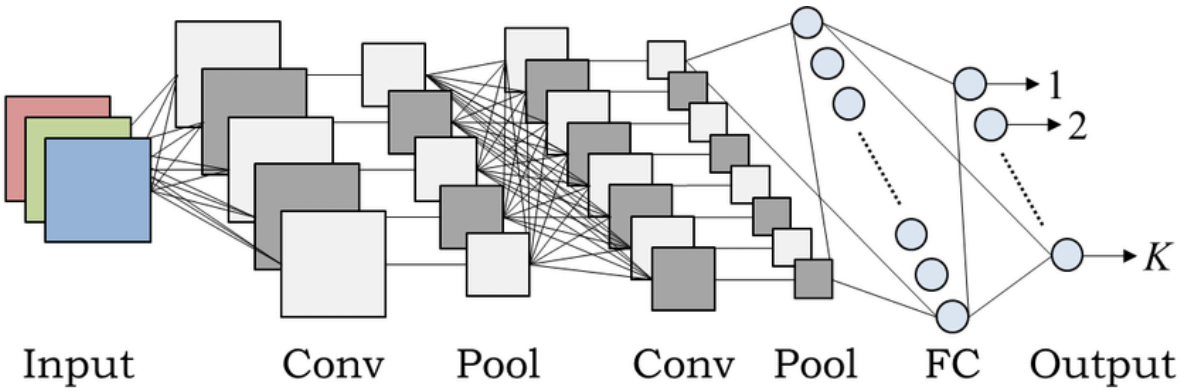

Figure 2. An example of CNN architecture.

Compare to normal neural network, CNNs have more layers to approach the high dimension data. As you can see in the Figure 2 above is an example that CNNs have more layers than a single line like other neural network. To go deeper in neural network, CNNs have many of neurons which share the same parameterization (weight vector and bias). Replicating neurons in this way allows for features to be detected regardless of their position in the input space. Moreover, weight sharing increases learning efficiency by greatly reducing the number of free parameters being learnt. The constraints on the model enable CNNs to achieve better generalization on the model enable CNNs to achieve better generalization on vision problems. We will to the detail about 2 kind layers are the most popular that will present below.

Convolutional Layer:

Convolution is a mathematical operation that's used in single that's used in single processing to filter signals. In a convolutional layer, all the neurons will apply to convolution operations to the inputs, namely convolutional neurons. The most important parameter in a convolutional neuron is the filter size. So that it makes the convolutional layer is the core building block of a CNN. Moreover, from the way that convolutional layers work, each filter is convolved across the width and height of the input volume, computing the dot product between the entries of the filter and the input and producing a 2D activation map. From that, we will have a result that the network learns filters that will activate when it detects some specific type of feature at some spatial position in the input.

Pooling layer

Pooling layer is a nonlinear layer, that work with width and height of the image from the dataset that we put on to train. It will perform a down sampling operation on. As we can see, from that we have a result that the image volume that we put in is reduced. This means that if some feature has already been identified in the previous convolution operation, that a detailed image is no longer needed for further processing, and it is compressed to less detailed picture.

So, from what we mentioned above, we can see that the pooling layer is mostly used immediately after the convolutional layer to reduce the spatial size. The most common form that pooling layer always use is Max pooling where we take a filter of size F*F and apply the maximum operation over the F*F sized part of the image.

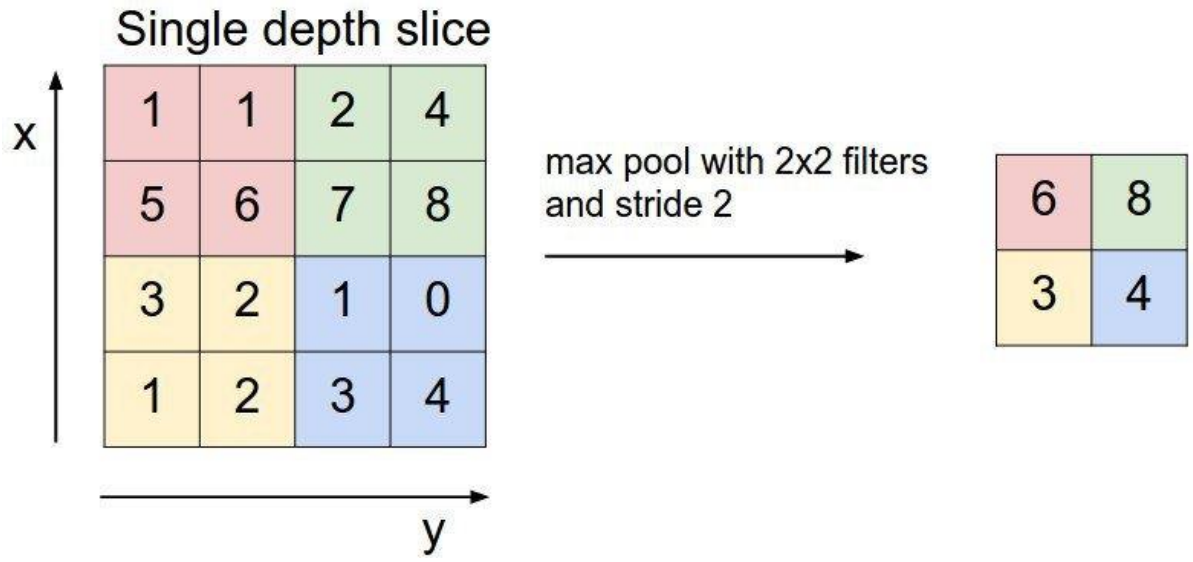

Figure 3. An example about Max pooling

From the figure about we can see that max pool size 2 x 2 with a stride of 2. Because with that we can calculate the formula that we will show below.

For example, that we have our input is of size w_1 x h_1 x d_1 and the size of the filter is F x F with stride S. Then the output sizes w_2 x h_2 x d_2 will be:

$w_2 = (w_1 – f)/S + 1$

$h_2 = (h_1 – f)/S + 1$

$d_2 = d_1$

So that with the size 2 x 2 with a stride of 2, it essentially reduces the size of input by half.

So why that we not take the average in place of taking maximum, because it will become average pooling and it will not make better result than max pooling.

Implemented CNN Architecture

Inspired by Maxout Network [7], we configure in our CNN models to five models. In each convolutional layer we set filter are 32, 64 ,128 ,256 and kernel size is (3,3) which determinate the width and height of the 2D convolution window. So that models can extract more features in the input shape to classify the plankton more correctly, because in plankton, there are many kinds of plankton that look very similar together and we cannot know what plankton belong to what type, so to deal with the problem, we come up with a solution that we must extract more features in the input shape so that computer can detected every kind of plankton and put it to their correctly categories. Like we had mentioned above, with the max pooling have size 2 x 2 to reduces the number of parameters within the mode and to generalizes the results from a convolutional filter - making the detection of features invariant to scale or orientation changes. Also, with these CNN structures for the purpose of reducing data dimension: the higher nodes of CNN will produce the fewer dimension of data before go to Fully

connected layer. To the detail of our implemented CNN design, it will be shown on the table below:

Model 1	Model 2	Model 3	Model 4	Model 5
32 nodes convenet	32 nodes convenet	32 nodes convenet	32 nodes convenet	32 nodes convenet
	64 nodes convenet	64 nodes convenet	64 nodes convenet	64 nodes convenet
	128 nodes convenet	128 nodes convenet	128 nodes convenet	128 nodes convenet
		256 nodes convenet	128 nodes convenet	128 nodes convenet
			256 nodes convenet	256 nodes convenet
			256 nodes convenet	256 nodes convenet
1024 fully	1024 fully	1024 fully	1024 fully	1024 fully
				2048 fully

Table 1. Models used in the platform

3. Web user interface

Since our primary aimed like we mentioned on the title plankton classification platform for supporting research activities of environmental scientists, it is more convenient to provide them with a graphical user interface to use our classification platform. For this, we develop a website acting as a web user interface for our plankton classification platform.

A detail of our design and implementation is presented in the following.

In order to build our front-end for users to interact directly, we use the skill that we had studied from the course web application. We use HTML (Hypertext Markup Language), CSS (Cascading Style Sheets), Javascript, Jquery to design our web framework. However, in CSS part, there are too much style we use very complicated so mostly we used a high level of CSS technique, namely SASS (Syntactically awesome style sheets). We choose SASS for our most thing in CSS because SASS can provide us variable to set and use when we making website interface. Moreover, SASS can help to design web complicated interface.

IV. Experimental Results and Discussion

1. Experimental setup

a. Dataset

Our data presented here are subset of a larger plankton imagery data set contain millions of images of microscopic marine plankton, organized according to category

labels provided by researcher at the Wood Hole Oceanographic Institution (WHOI). The images are currently placed into 6 Domains of plankton: Diatoms, Flagellates, Dinoflagellates, Ciliates, Coccolithophore, Miscellaneous. To the detail, in each domain, there are many types of plankton. There are total 103 types of plankton in 103 folders. These images were collected in situ by automated submersible imaging-in-flow cytometry with an instrument called imaging FlowCytobot (IFCB) [8]. Our data that we use on this project take from 2010 to 2014 (There are total 1,980,000 images in 103 folder)

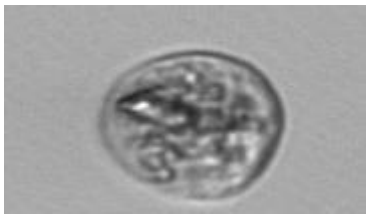

Figure 4. An image of plankton in our data set

In our plankton data set that we extracted from the raw data were sorted into 103 plankton classes, so that we split 6:3:1 into train, validation and test datasets.

b. Data Preprocessing

In our dataset, there are many images with different resolution, the smallest ones are less than 50 x 50 pixels, whereas the largest ones are up to 1000 x 1000 pixels, even some images will come up with 500 x 1000 pixels or 148 x 200 pixels. Therefore, we decided that we rescaled in fixed dimension: 128 x 128 pixels in order to unified all images on a resolution. To improve the stability and convergences of the model.

However, there are some folder of plankton datasets only contain few images or less than 200 images. With this problem, this will cause us overfitting our training model. So, we used data augmentations to handle randomly during training for preventing overfitting. The parameters of data augmentations are presented below:

- Rotation: random with angle between 0 – 180 degree
- Width shift and height shift: randomly translate pictures 0.2 vertically or 0.2 horizontally
- Rescale: Target values between 0 and 1 by scaling with a 1/255
- Shear range: randomly applying 0.2 shearing transformations
- Zoom range: 0.2 for randomly zooming inside pictures
- Horizontal flip: randomly flipping half of the images horizontally - relevant when there are no assumptions of horizontal asymmetry. We set to True.
- Fill mode: it’s a strategy used for filling in newly created pixels, which can appear after a rotation or width/height shift. We set nearest.

c. Training and Validating

Like we just mentioned above we divided our data set with the ratio is 6:3:1. The training process with bath size is 8, and samples that we put to train per epoch is 1000 and validation steps is 500. The learning rate is initialized at 0.0001 and a learning rate decay of 0.0001 is applied after each epoch.

Accuracy = total true sample / total sample

2. Result and discussion

Effect of number of neural network layers:

Overall, the accuracy of all neural network training until now have passed 80% (see the table below) and the time of training also increase with the number of layers as a function like n^a. As you can see, from the table below, we achieve the best result with model 5 and the best accuracy that we gain from our training data is 83.3% with our training CNN model. From the list table below, through time, we increase the number of neural network layer, it gains more accuracy. As increasing the number of convolutional layers like the solution that we mentioned above, in order to extract more features in the input shape so that computer can detected every kind of plankton and put it to their correctly categories. However, it will end up overfitting model to the training data and it will not do well with unseen data. So, we did not want try to increase more layer, since we had achieved a good result.

Number of neural network layer	Time (hr)	Accuracy (%)
2	7.1	73.1
3	7.8	76.4
4	8.1	80.1
5	8.5	83.3

Table 2. Result table

Plankton characteristics classified by the platform:

As the result is scientific name of plankton, more characteristics of that plankton can be known. According to Jane M. Browles [9] and Jerry G. Johnson [10], the scientific name is in Latin name and consists of two parts: the genus or generic name and the specific epithet. So that, from the name of plankton, the properties of plankton can be almost understood and this is very useful for further research.

Website interaction:

Our website, basically is a hybrid website, that combine a news website about plankton and a huge gallery that people can access to it, and also people can contribute our data through our website. To the detail, with the part news website, people will just use it for update their information about new story, or new discovery about new kind of plankton or something else that relate to plankton. And about the gallery part, people will access to it to find what their plankton images that they want to see, also, people can upload their image about plankton to this website with only few easy steps.

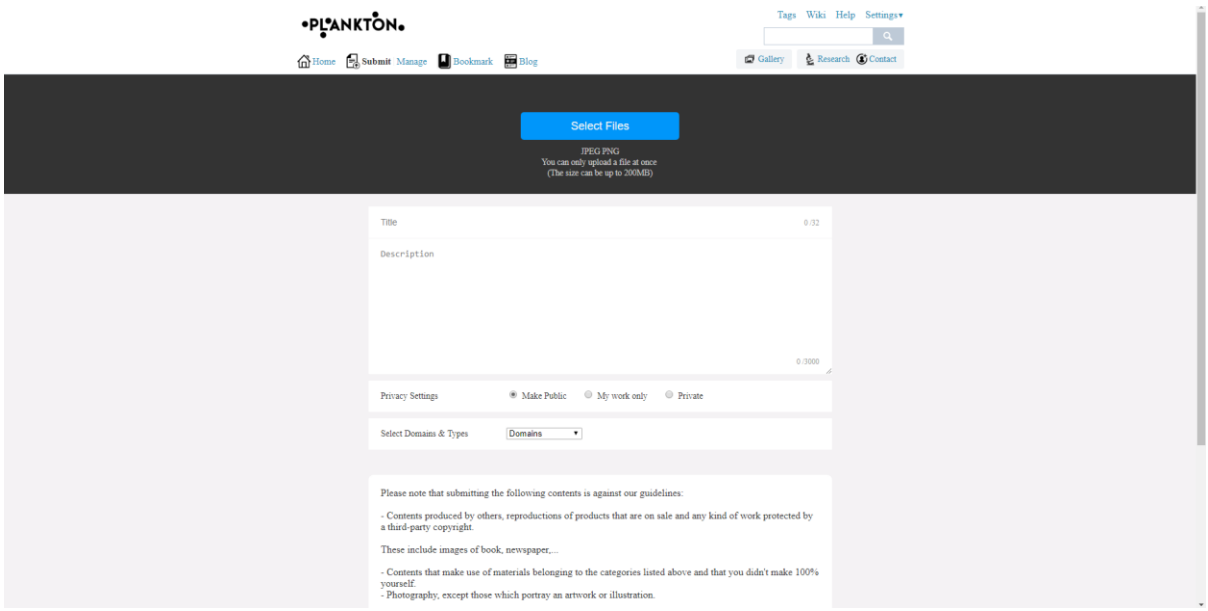

Figure 5. Web interface

If the image that already that exist in the website database, the website will immediately warn the user that this image had already had on our data, so it can be uploaded to our data.

Also base on “intellectual property”, we applied some law to our website to write term of use. In order let people understand that people cannot reup images that already exist in our database.

V. Conclusion and Future Works

In the project, the accuracy of the experiment that until now, we have is over 80%. However, that only the number that we use for only a domain in our data. We haven’t yet used all the domain in WHOI’s plankton dataset for training. We are trying to make it work for real at the moment. But to comparing with the classification rate achieved by machine learning method to human accuracy that over 80% is a fine number.

For the future work, this would be possible to improve the activities of the website. For the time being, we only make it can be uploaded the image to our website and move it to our database so people can used it. In the future, we also want that people from outside also can write article and upload it to blog page in our website. So, people can

learn something from the point of view of the people write it and uploaded to our website.

VI. Management of The Project at The End

Activities	Plan	Expected results	Done
Research of Plankton	+) Understand overall characteristic and a bit knowledge of plankton +) Understand 6 domains of plankton +) Prepare the content about plankton	+) Understand overall characteristic and a bit knowledge of plankton +) Understand 6 domains of plankton +) Prepare the content about plankton	+) Understand overall characteristic and a bit knowledge of plankton +) Understand 6 domains of plankton +) Prepare the content about plankton
Preparing detailed information about plankton and code	All required software is installed	Everything is ready for testing	+) Collected and checked all the articles and documents +) Downloaded database (103 types of plankton) from Wood Hole Oceanographic Institution (WHOI)
Model Development	+) Data exportation +) Image preprocessing + Apply machine learning for building a model	The model has accepted classification score	The model reaches up to over 80% (For only one domain that we are now testing, not the whole data) – It's a good result, since there are many mistakes that we had fixed.
Website Development	+) Design website of plankton classification	+) Simple and responsive user interface +) Can use pre-built model to recognize plankton	Website is simple and friendly to user
Writing	+) Preparing the	+) Completed on time	+) Well checked

report and preparing for the final presentation	slides for presentation. +) Practicing the presentation +) Think and ready for every possible question that may come up +) Writing report	+) Well prepared the slides for presentation +) All important information is covered +) Come up with many questions that may asked during presentation	before submitting report. +) Prepared well for presentation +) All important information is covered +) Be sure all members understand well their own task and of others

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