Udacity Term 2 Robotic Inference Project

Abstract

This project has two classification data models using Deep Neural Network technology. The first one is classifying the bottles, candy wrappers and nothing on a moving belt. The second one classified the dog A, dog B or nothing. The image data are come from public dataset. The project used the three model: AlexNet, GoogLeNet and LeNet. For both classifications, the best results were presented in this article.

Introduction

Classification includes a broad range of decision-theoretic approaches to the identification of images (or parts thereof). All classification algorithms are based on the assumption that the image in question depicts one or more features (*e.g.*, geometric parts in the case of a manufacturing classification system, or spectral regions in the case of remote sensing) and that each of these features belongs to one of several distinct and exclusive classes. The classes may be specified *a priori* by an analyst (as in *supervised classification*) or automatically clustered (*i.e.* as in *unsupervised classification*) into sets of prototype classes, where the analyst merely specifies the number of desired categories[1].

In this project used NVIDIA's DIGITS workflow[2] to rapidly prototype ideas that can be deployed on the Jetson in close to real time. The DIGITS will prototype classification networks, detection networks, segmentation networks!

There are two parts in the project:

1. P1 moving belt image classification part used P1 dataset pictures of candy boxes, bottles, and nothing (empty conveyor belt).
2. Dog image classification part used the dog image dataset (dog A, dog B and nothing) which Author collected from iPhone.

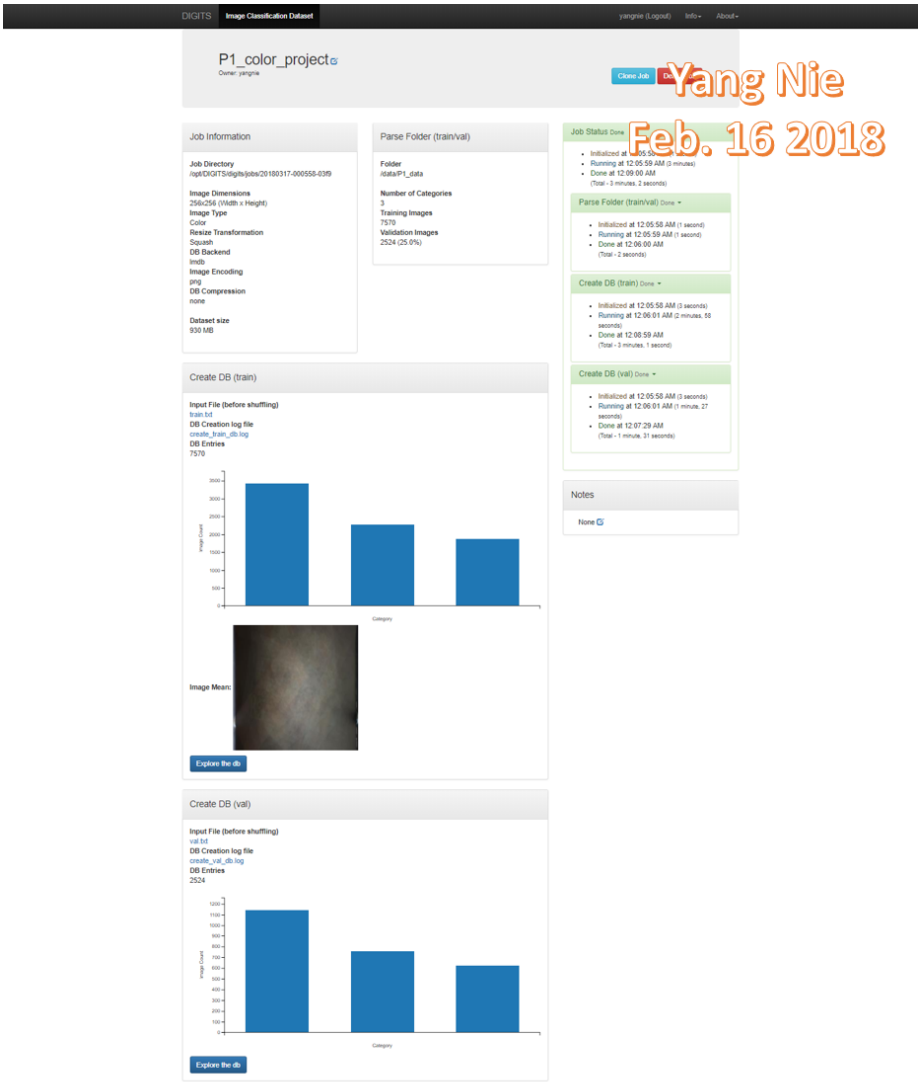
Background / Formulation

1. P1 moving belt image classification

The P1 image dataset is stored in /data/P1/ directory. It include all images of bottles, candy wrappers and no object on a conveyor belt passing under a camera. A swing arm is used to sort all right objects to correct the bins depending on classifying results.

P1 dataset image example:

P1 dataset was split two training and validation parts, the color image size is 256 X 256



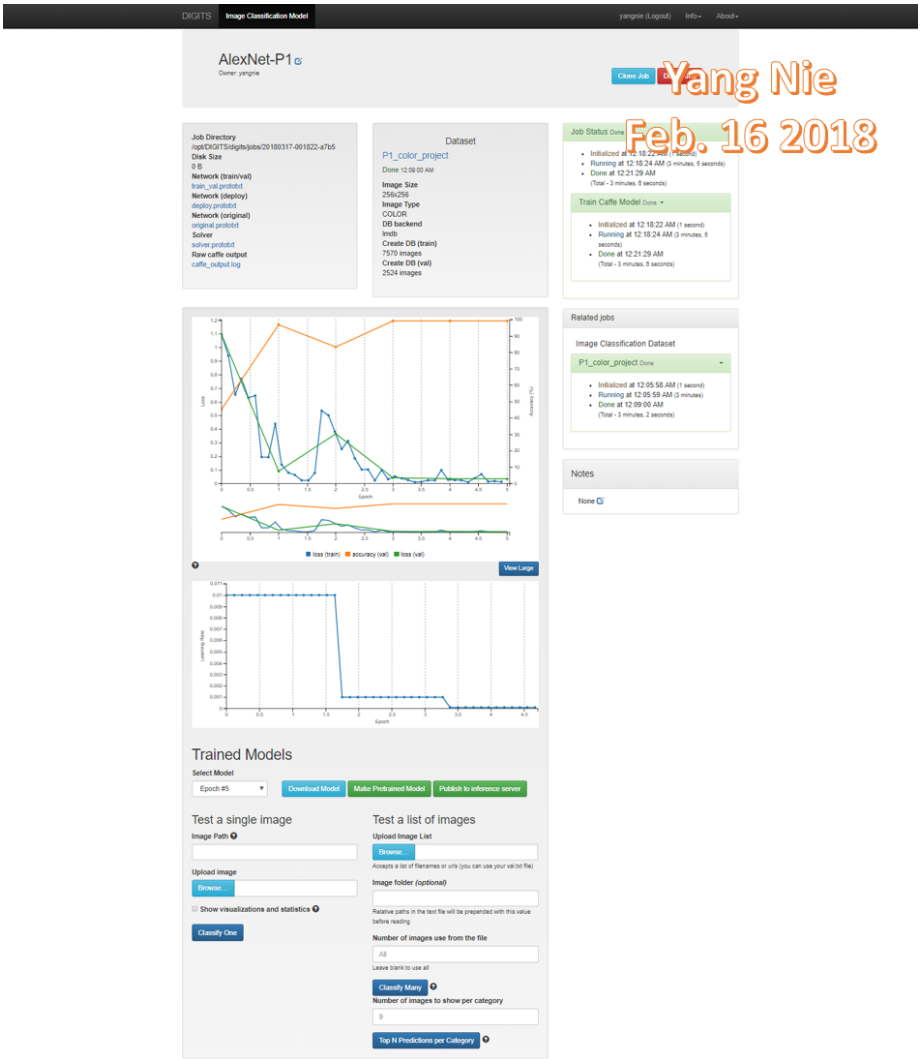
Data Acquisition:

The P1 dataset is provided from Udacity Robotics lesson.

It were split to two sets: training and validation dataset. They are color image and size is 256 x 256. This dataset is provided from Udacity robotics class.

Model creation:

AlexNet Model was built as:



GoogLeNet Model was built as:

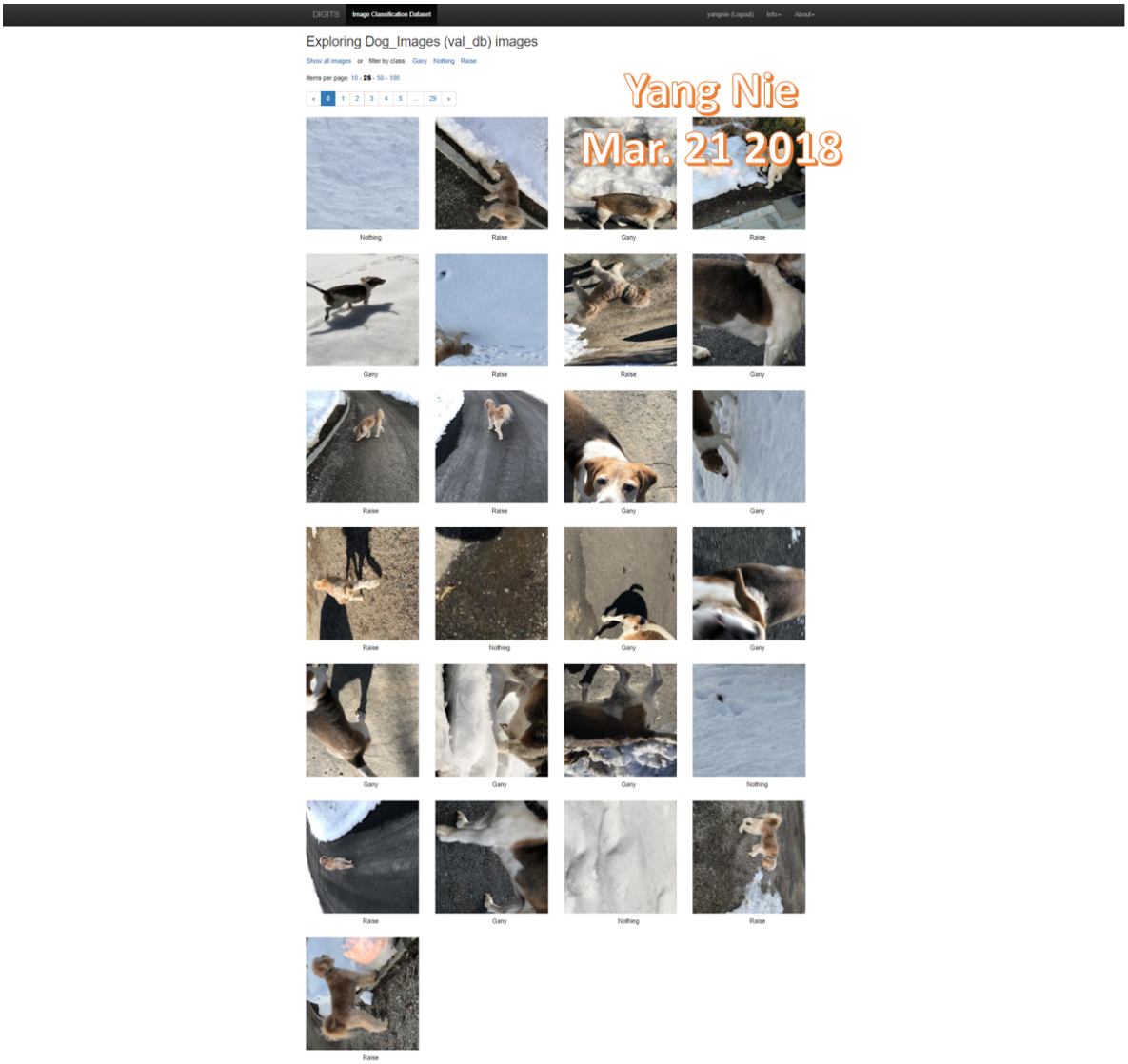
The parameter setting:

Both epoch were set to 5. All other parameters used as default.

2. Dog image classification

The dog image files located in Output folder, it includes three subfolders, Gany for dog A, Raise for dog B, Nothing for no object.

Dog image example:



Dog image dataset was split three training, validation and test parts, the color image size is 256 X 256

DIGITS | Image Classification Dataset | yangnie (Logout) | Info | About

Dog_Images

Owner: yangnie

Clone Job | Delete Job

Yang Nie
Mar. 21 2018

Job Information

Job Directory
/opt/DIGITS/digits/jobs/20180321-182200-7ee0

Image Dimensions
256x256 (Width x Height)
Image Type
Color
Resize Transformation
Squash
DB Backend
lmdb
Image Encoding
png
DB Compression
none

Dataset size
264 MB

Parse Folder (train/val/test)

Folder
/home/workspace/Output

Number of Categories
3
Training Images
2182
Validation Images
698 (24.0%)
Test images
28 (1.0%)

- Initialized at 06:22:00 PM (1 second)
- Running at 06:22:01 PM (1 minute, 11 seconds)
- Done at [illegible] PM
(Total - 1 minute, [illegible])

Parse Folder (train/val/test) Done

- Initialized at 06:22:00 PM (1 second)
- Running at 06:22:02 PM (1 second)
- Done at 06:22:03 PM
(Total - 2 seconds)

Create DB (train) Done

- Initialized at 06:22:00 PM (2 seconds)
- Running at 06:22:03 PM (1 minute, 9 seconds)
- Done at 06:23:12 PM
(Total - 1 minute, 12 seconds)

Create DB (val) Done

- Initialized at 06:22:00 PM (2 seconds)
- Running at 06:22:03 PM (30 seconds)
- Done at 06:22:33 PM
(Total - 32 seconds)

Create DB (test) Done

- Initialized at 06:22:00 PM (2 seconds)
- Running at 06:22:03 PM (2 seconds)
- Done at 06:22:05 PM
(Total - 5 seconds)

Create DB (train)

Input File (before shuffling)
train.txt
DB Creation log file
create_train_db.log
DB Entries
2182

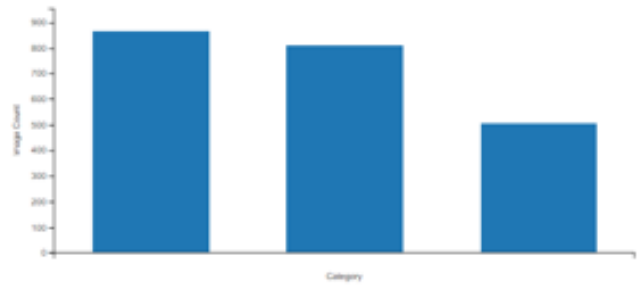
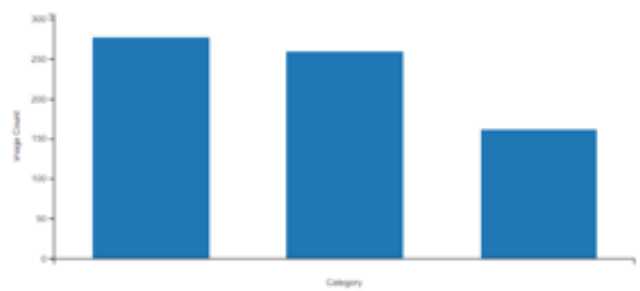


Image Mean:

Explore the db

Create DB (val)

Input File (before shuffling)
val.txt
DB Creation log file
create_val_db.log
DB Entries
698



Explore the db

Notes

None

Data Acquisition:

The dog images were taken from iPhone, then used Augmentation[3] code to generate 500 to 1000 additional images depend the object type.

	Dog A (Dany)	Dog B (Raise)	No object (Nothing)
iPhone images	193	156	62
Augment generated images	887	998	612
Total images	1080	1154	674

The dog database was created as:

	Training	Validating	Testing
Image number	2185	695	28
Percentage	75%	24%	1%

Model creation:

GoogLeNet Model was built as:

DIGITS | Image Classification Model | yangnie (Logout) | Info | About

GoogLeNet_Dog_50

Owner: yangnie

Clone Job | Delete Job

Yang Nie

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Job Directory
/opt/DIGITS/digits/jobs/20180321-191601-e56c
Disk Size
0 B
Network (train/val)
train_val.prototxt
Network (deploy)
deploy.prototxt
Network (original)
original.prototxt
Solver
solver.prototxt
Raw caffe output
caffe_output.log

Dataset

Dog_Images

Done 06:23:13 PM

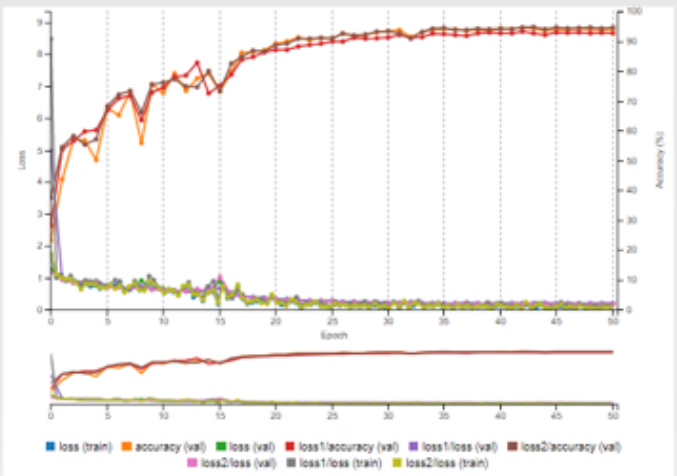
Image Size
256x256
Image Type
COLOR
DB backend
lmdb
Create DB (train)
2182 images
Create DB (val)
698 images
Create DB (test)
28 images

Job Status Done

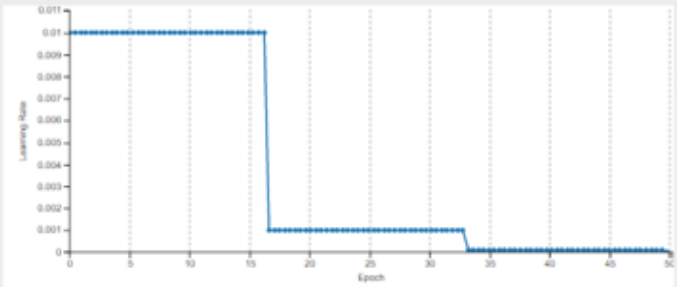
- Initialized at 07:16:01 PM (1 second)
- Running at 07:16:02 PM (26 minutes, 26 seconds)
- Done at 07:42:29 PM
(Total - 26 minutes, 27 seconds)

Train Caffe Model Done

- Initialized at 07:16:01 PM (1 second)
- Running at 07:16:02 PM (26 minutes, 26 seconds)
- Done at 07:42:29 PM
(Total - 26 minutes, 27 seconds)



View Large



Trained Models

Select Model

Epoch #50 | Download Model | Make Pretrained Model | Publish to inference server

Test a single image

Image Path

Upload image

Browse...

Show visualizations and statistics

Classify One

Test a list of images

Upload Image List

Browse... test28.txt

Accepts a list of filenames or urls (you can use your val.txt file)

Image folder *(optional)*

Relative paths in the text file will be prepended with this value before reading

Number of images use from the file

All

Leave blank to use all

Classify Many

Related jobs

Image Classification Dataset

Dog_Images Done

- Initialized at 06:22:00 PM (1 second)
- Running at 06:22:01 PM (1 minute, 11 seconds)
- Done at 06:23:13 PM
(Total - 1 minute, 12 seconds)

Image Classification Model

AlexNet_Dog Done

- Initialized at 06:25:52 PM (1 second)
- Running at 06:25:53 PM (3 minutes, 47 seconds)
- Done at 06:29:41 PM
(Total - 3 minutes, 49 seconds)

GoogLeNet_Dog Done

- Initialized at 06:44:29 PM (1 second)
- Running at 06:44:30 PM (10 minutes, 58 seconds)
- Done at 06:55:29 PM
(Total - 10 minutes, 59 seconds)

Notes

None

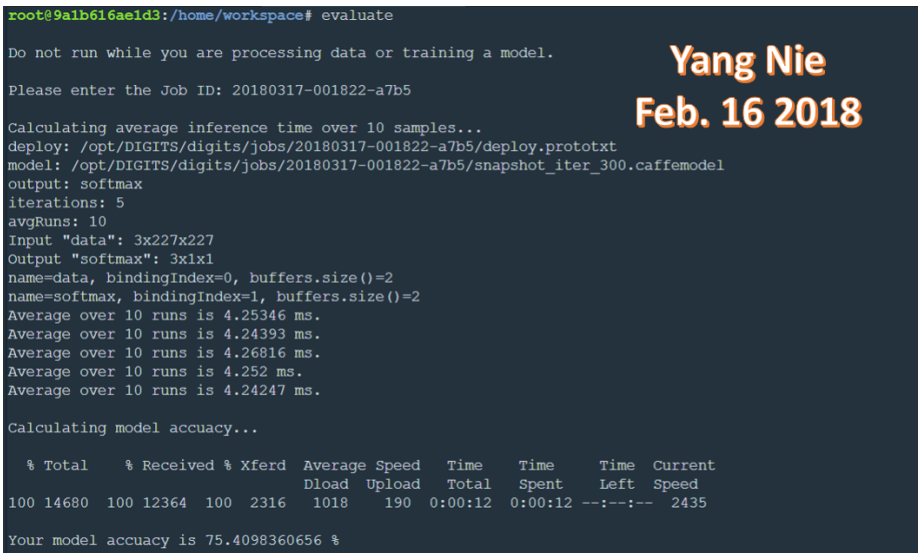
The parameter setting:

Both epoch were set to 50 and Batch size = 50. All other parameters used as default.

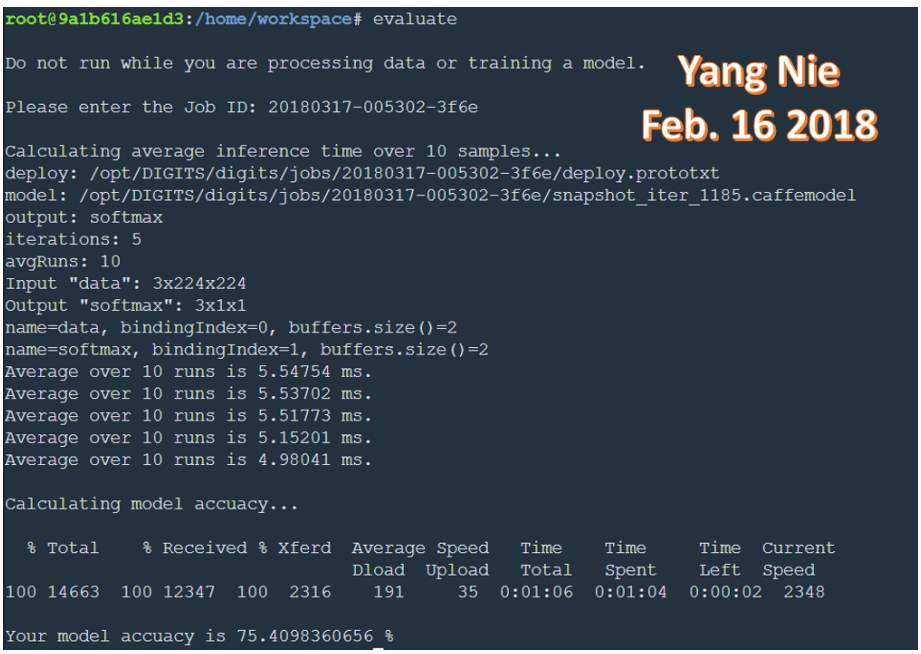
Results

1. P1 moving belt image classification

Evaluating result for AlexNet Model as:



Evaluating result for GoogLeNet Model as:

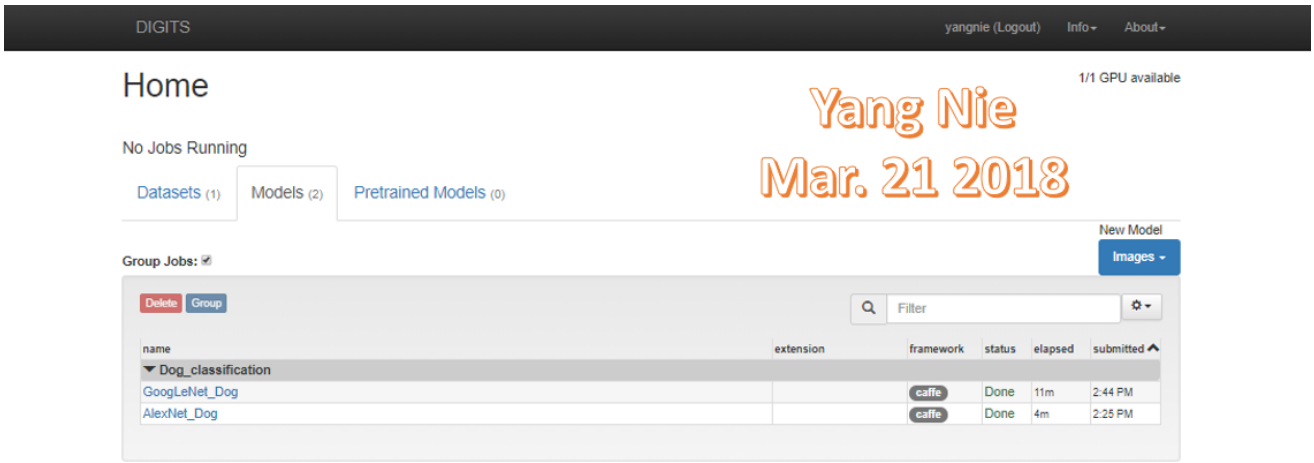


Both AlexNet and GoogLeNet models are at least 75 percent accuracy and an inference time of less than 10 ms.

	AlexNet	GoogLeNet
Accuacy	75.4090360656%	75.4090360656%
Average inference Time	4.254004 ms	5.34768 ms

2. Dog image classification

AlexNet and GoogLeNet models, both were built and tested. Compare both of them, the GoogLeNet model has better results. This article only shows GoogLeNet model result.



This is GoogLeNet model results (epoch = 50, batch size = 50): The result is very good, the accuracy for all three classes are 100%.

Note: The number in table is the number of image:

	Dog A (Gany)	Dog B (Raise)	No object (Nothing)	Per-class accuracy
Dog A (Gany)	11	0	0	100%
Dog B (Raise)	0	11	0	100%
No object (Nothing)	0	0	6	100%

Digits test results screen copy:

DIGITS GoogLeNet_Dog_50 **Classify Many** yangnie (Logout) Info About

Classify Many Images

Owner: yangnie

Yang Nie

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Delete Job

GoogLeNet_Dog_50 Image Classification Mode

- Running at 07:43:58 PM (3 seconds)
- Done at 07:44:01 PM

(Total - 4 seconds)

Infer Model Done

Summary

Top-1 accuracy
100.0%

Top-5 accuracy
100.0%

Notes

None

Confusion matrix

	Gany	Nothing	Raise	Per-class accuracy
Gany	11	0	0	100.0%
Nothing	0	6	0	100.0%
Raise	0	0	11	100.0%

All classifications

	Path	Ground truth	Top predictions					
1	/home/workspace/Output/Gany/Gany_original_d97e01fc-4db5-41fc-8f34-f953582da95d.JPG	Gany	Gany	96.29%	Raise	3.62%	Nothing	0.1%
2	/home/workspace/Output/Gany/Gany_original_0bad9fc7-480f-4fc8-8321-30e74628ccc3.JPG	Gany	Gany	100.0%	Nothing	0.0%	Raise	0.0%
3	/home/workspace/Output/Gany/Gany_original_fa10d8e7-401d-4d5d-91c0-08987c786fb8.JPG	Gany	Gany	100.0%	Raise	0.0%	Nothing	0.0%
4	/home/workspace/Output/Gany/Gany_original_4f9fb6e8-a9d8-412c-992c-0539260cba76.JPG	Gany	Gany	99.99%	Nothing	0.01%	Raise	0.01%
5	/home/workspace/Output/Gany/Gany_original_eb093c9d-64af-4360-b6cd-74b2ebcac2b0.JPG	Gany	Gany	99.87%	Nothing	0.11%	Raise	0.02%
6	/home/workspace/Output/Gany/Gany_original_ab87266c-fbe3-402f-b18b-57af716ea280.JPG	Gany	Gany	83.69%	Nothing	16.23%	Raise	0.08%
7	/home/workspace/Output/Gany/Gany_original_90fd2d01-4e24-432f-85da-30955095c13a.JPG	Gany	Gany	99.98%	Raise	0.02%	Nothing	0.0%
8	/home/workspace/Output/Gany/Gany_original_e688cc17-6081-4d09-ae79-534f46ae6587.JPG	Gany	Gany	99.97%	Nothing	0.02%	Raise	0.01%
9	/home/workspace/Output/Gany/Gany_original_141fc080-cc9a-4ba1-9586-eed0efb7d65d.JPG	Gany	Gany	99.7%	Raise	0.22%	Nothing	0.08%
10	/home/workspace/Output/Gany/Gany_original_5ed4651e-07ce-49db-8f97-1c1a8e274986.JPG	Gany	Gany	99.9%	Raise	0.08%	Nothing	0.02%
11	/home/workspace/Output/Gany/Gany_original_4a6ac335-7e1e-4a36-bb18-d5ce7d6ce930.JPG	Gany	Gany	99.96%	Nothing	0.03%	Raise	0.0%
12	/home/workspace/Output/Nothing/Nothing_original_ecef059d-59ae-4fcf-85d9-2a64c55e0c79.JPG	Nothing	Nothing	93.96%	Gany	6.02%	Raise	0.02%
13	/home/workspace/Output/Nothing/Nothing_original_b084f654-7f4f-4879-bbad-9492f56f48b3.JPG	Nothing	Nothing	95.47%	Gany	4.43%	Raise	0.1%
14	/home/workspace/Output/Nothing/Nothing_original_85d88e53-8e65-41b3-91d8-905e2238aac6.JPG	Nothing	Nothing	97.03%	Gany	2.96%	Raise	0.01%
15	/home/workspace/Output/Nothing/Gany_original_96808377-3801-44db-8b66-df3b147482c8.JPG	Nothing	Nothing	95.4%	Gany	4.58%	Raise	0.02%
16	/home/workspace/Output/Nothing/Nothing_original_1c5b12bc-b35c-43cd-9bf9-eb2fa378bede.JPG	Nothing	Nothing	96.11%	Gany	3.79%	Raise	0.1%
17	/home/workspace/Output/Nothing/Nothing_original_d4e2617e-ed08-4c34-a7d2-5e954e0dbd56.JPG	Nothing	Nothing	95.51%	Gany	4.27%	Raise	0.22%
18	/home/workspace/Output/Raise/Raise_original_2ddbb959-8605-47b8-9865-06cbf775d5df.JPG	Raise	Raise	99.86%	Gany	0.14%	Nothing	0.0%
19	/home/workspace/Output/Raise/Raise_original_55684438-2c1b-4744-be1b-c849af01afff.JPG	Raise	Raise	99.98%	Gany	0.02%	Nothing	0.0%
20	/home/workspace/Output/Raise/Raise_original_5e4c19c1-320d-45b0-abb1-d44db5e21296.JPG	Raise	Raise	99.99%	Gany	0.01%	Nothing	0.0%
21	/home/workspace/Output/Raise/Raise_original_8f2df227-47a5-4809-8117-09f6eca56d33.JPG	Raise	Raise	99.98%	Gany	0.02%	Nothing	0.0%
22	/home/workspace/Output/Raise/Raise_original_9a54f995-ad86-48e4-a341-c0259780b1f1.JPG	Raise	Raise	99.86%	Gany	0.14%	Nothing	0.0%
23	/home/workspace/Output/Raise/Raise_original_4dec83e7-d155-4383-9e50-62ae8474ac88.JPG	Raise	Raise	97.64%	Gany	2.33%	Nothing	0.04%
24	/home/workspace/Output/Raise/Raise_original_12c69b1c-172f-499c-baef-0c7746740eb7.JPG	Raise	Raise	99.98%	Gany	0.02%	Nothing	0.0%
25	/home/workspace/Output/Raise/Raise_original_a5927ea1-f9e4-4619-ac30-8cf8f0d8eec9.JPG	Raise	Raise	100.0%	Gany	0.0%	Nothing	0.0%
26	/home/workspace/Output/Raise/Raise_original_e5aee279-c626-41c5-904d-fb5090b0d516.JPG	Raise	Raise	99.68%	Gany	0.32%	Nothing	0.0%
27	/home/workspace/Output/Raise/Raise_original_d516920f-c088-48a2-bf3c-bb84a76a58db.JPG	Raise	Raise	100.0%	Gany	0.0%	Nothing	0.0%
28	/home/workspace/Output/Raise/Raise_original_151a2cf6-8c25-4218-a3d6-6a563ce02344.JPG	Raise	Raise	100.0%	Gany	0.0%	Nothing	0.0%

Discussion

The original images are almost covering full dog body, using augment code can easily generate different angle and different part of dog body images. There is no problem to use rotate, flip and resize functions to generate new images, but crop image function can cause some image problems if the new image didn't include the target object at all. The image source quality is very important for Deep Learning training result, the manually checking was applying all these generated images to make sure no any nothing image mixed in dog image classes.

Conclusion / Future Work

Using augmentation code to generate image is a good and fast way to get a large number of image.

The result used GoogLeNet model (with epoch = 50, Batch size = 50 and test dataset = 1% of total images) and plus image augmented images are very satisfied in classification image area.

Further work will include testing object detection and segmentation implementation, and deploying the model on Jetson TX2 board and testing them in real world environment.

References

[1] S. Perkins, A. Walker and E. Wolfart, Classification "https://homepages.inf.ed.ac.uk/rbf/HIPR2/classify.htm" 2003

[2] Nvidia, DIGITS workflow "https://developer.nvidia.com/digits" 2018

[3] Marcus D. Bloice, Augmentor "https://github.com/mdbloice/Augmentor" 2018