Litter Detection Algorithm: Programmer Manual

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1. Introduction

FixIT worked with Keep America Beautiful to create a Litter Detection Algorithm that will identify litter, visually, when given a particular image. This manual was written as an instructional guide for programmers and/or users with prior experience in computer science. We will outline our step-by-step process on how to access our server, use our algorithm, as well as how to manipulate the algorithm for future use.

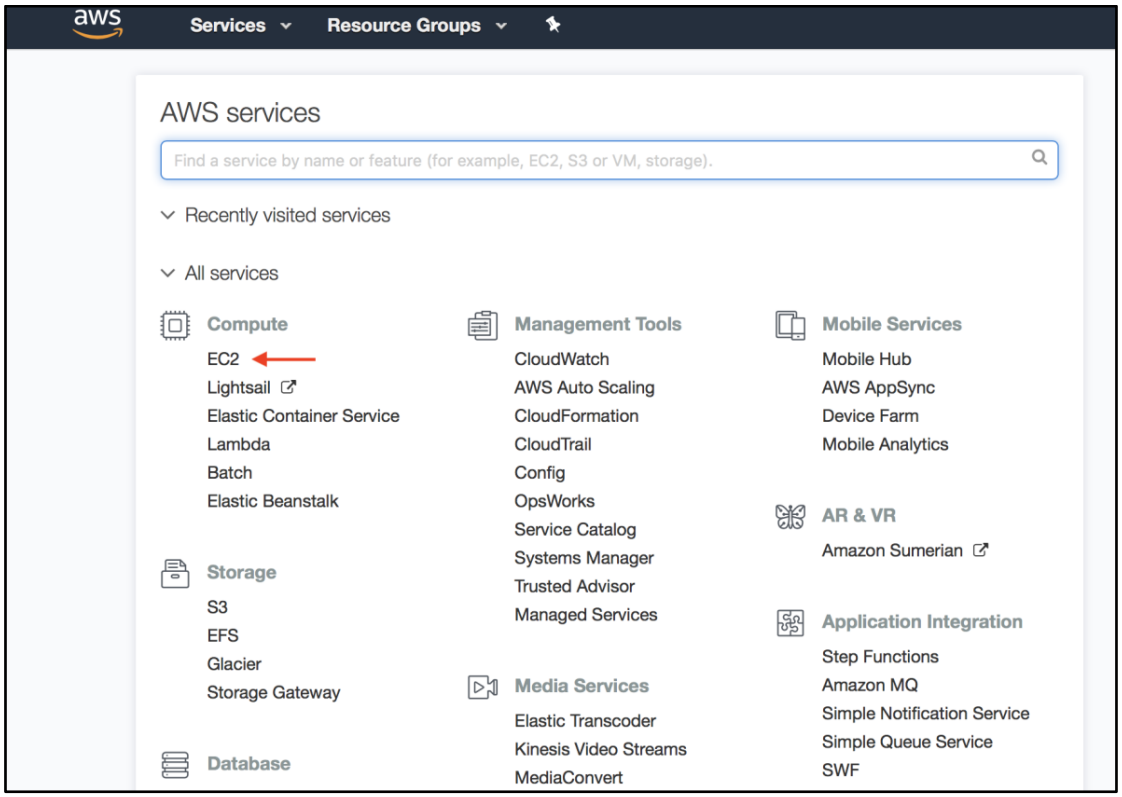
1.1 Tools

- **TensorFlow**
- **Amazon Web Services**
  - P2 Large Ubuntu Server
- **Jupyter Notebook**
- **Windows:**
  - PuTTY
- **Mac:**
  - Terminal

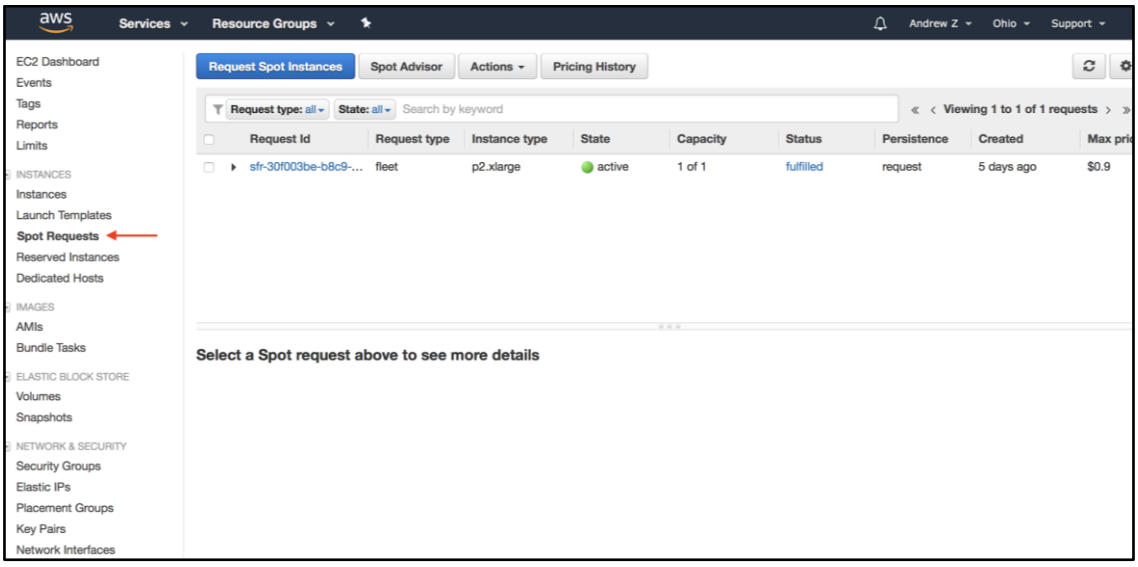
2. Creating an AWS ec2 Server Instance

2.1 Spot instance server

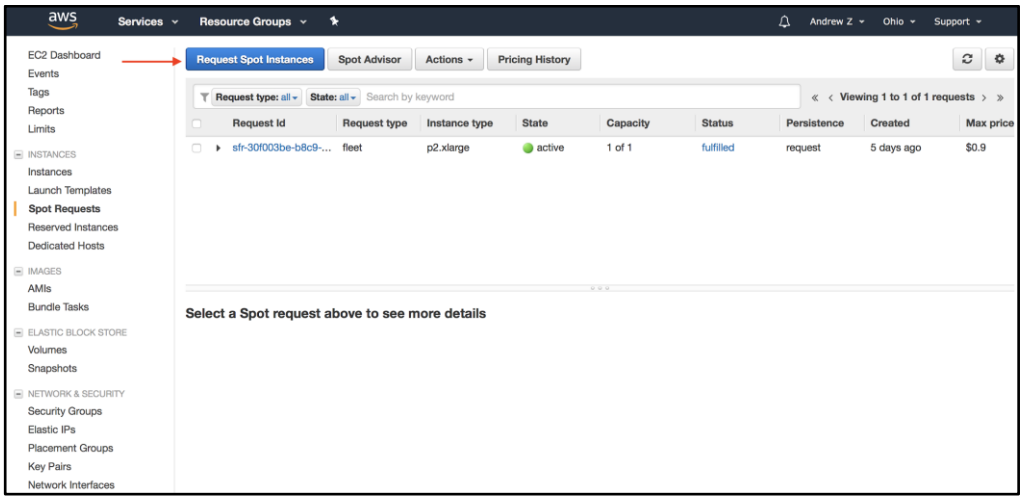
1. Create aws account: https://portal.aws.amazon.com/billing/signup?nc2=h_ct&redirect_url=https%3A%2F%2Faws.amazon.com%2Fregistration-confirmation#/start
2. Go to aws service dashboard. https://us-east-2.console.aws.amazon.com/console/home?region=us-east-2
3. Look under Computer category in all services and select EC2



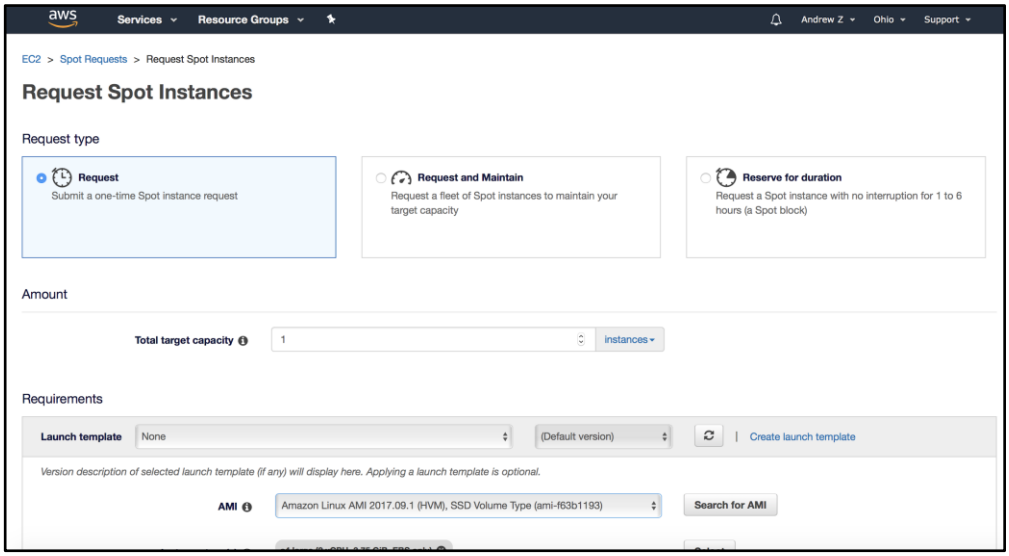
4. Once you get to the EC2 dashboard page, look at the left hand navigation bar and select Spot Requests under instances.

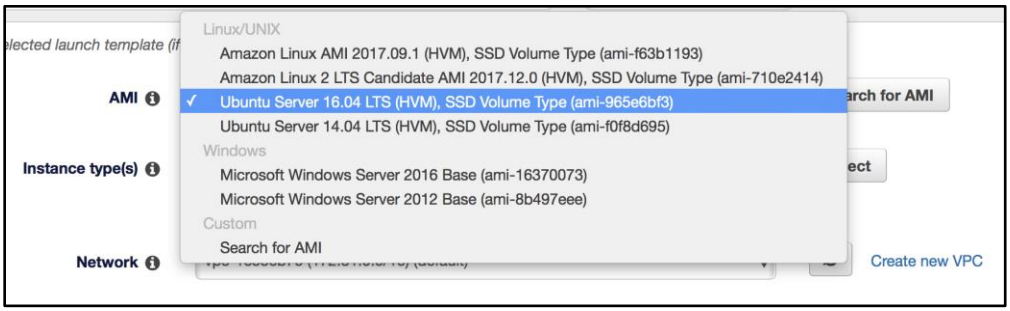


5. Click on Request spot instances.



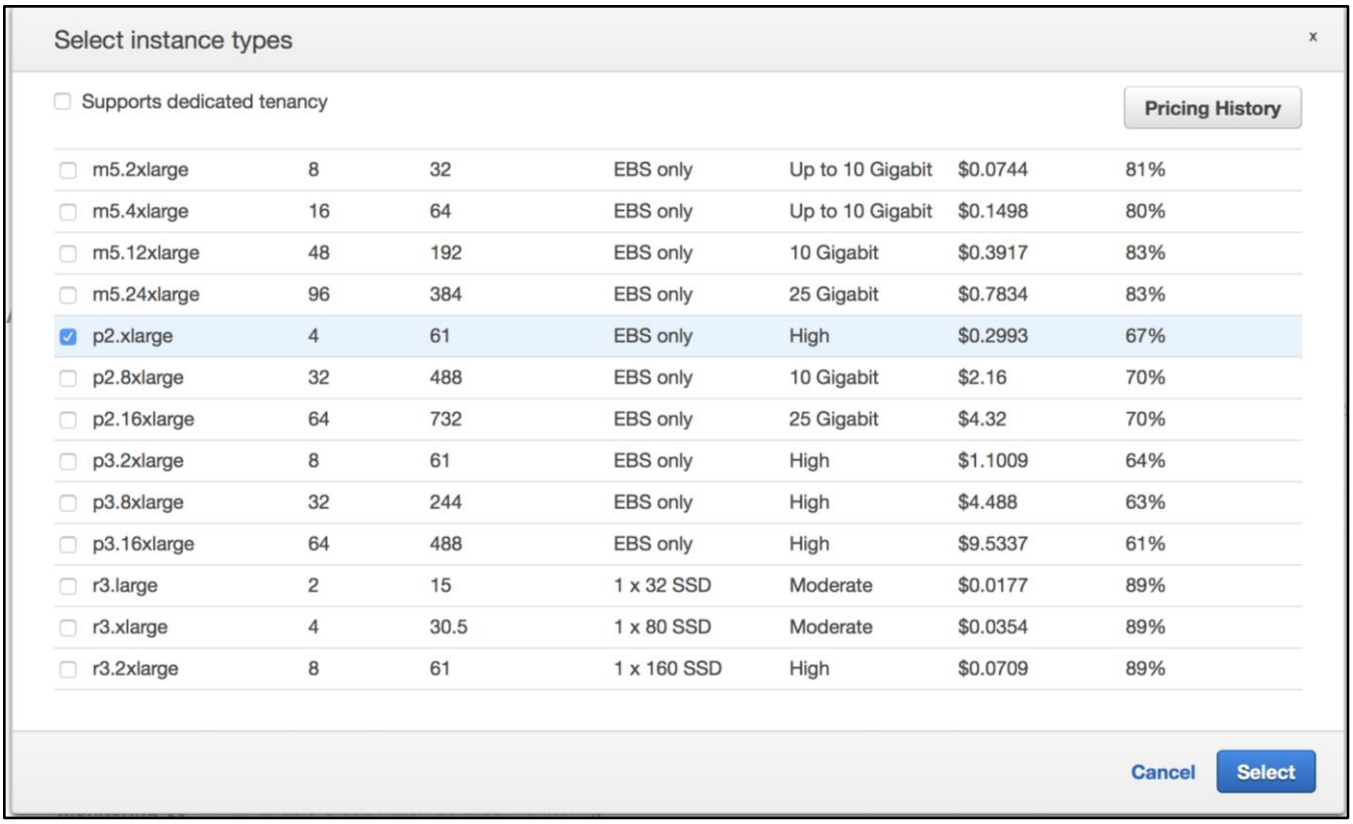
6. You'll end up at the page for editing the settings of your spot instances. For most you will just use the default settings





7. First go to AMI option, scroll through the options listed or click on search for AMI. For ours we used an Ubuntu Server 16.04.
8. Next go to Instance types, and hit select.

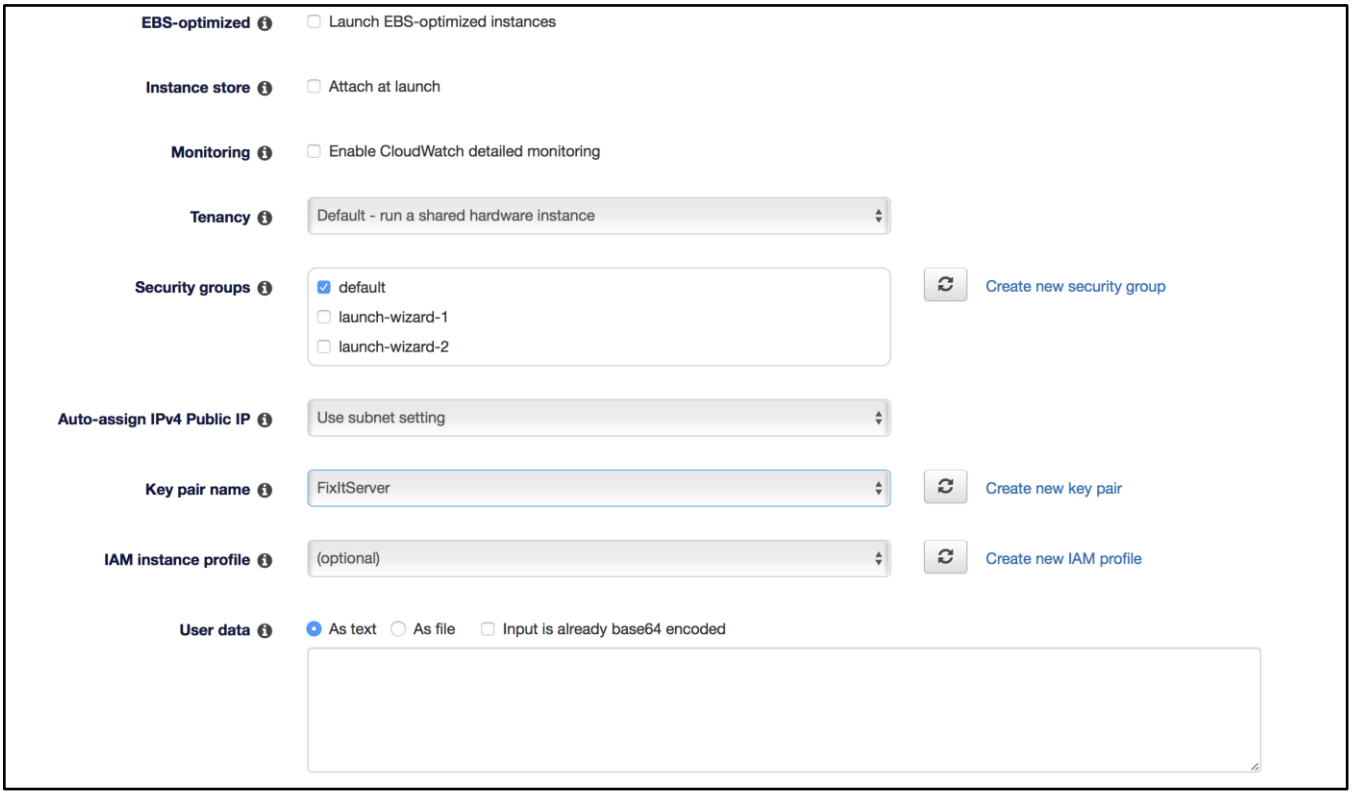
9. It'll bring you to a list of of instance types.



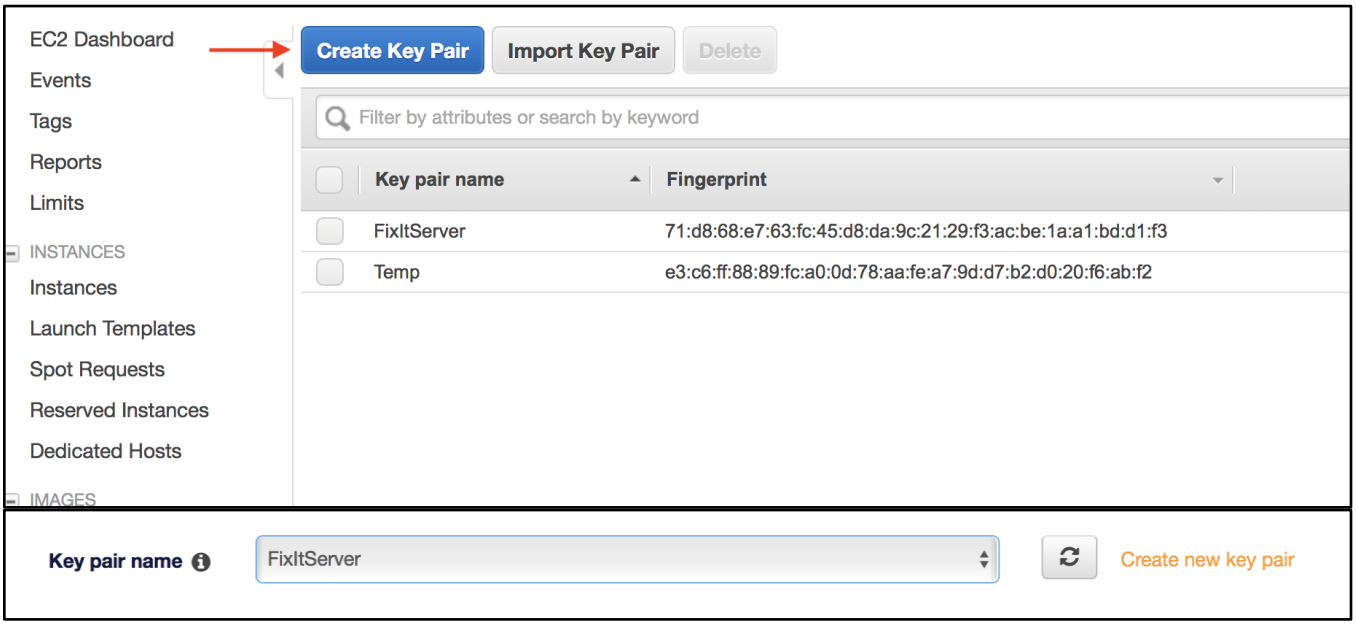
10. The one we use is a p2xlarge. The reason we use a fairly expensive one is because it is recommended that you use a server with at least one gpu. GPU's improve the efficiency and time between each step when training significantly. P2xlarge to us is considered the minimum required to run the model training.

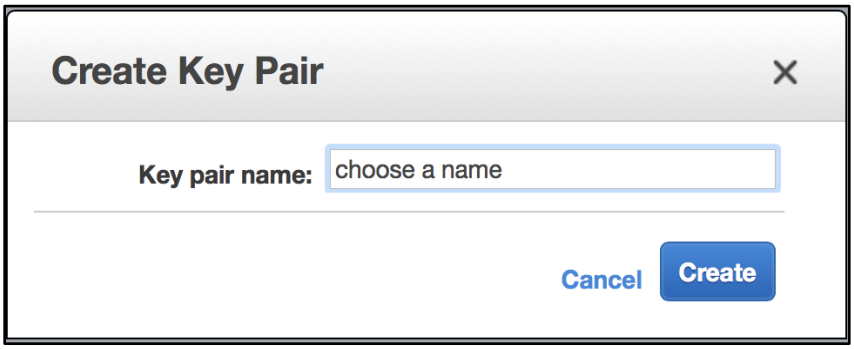
11. Next go to the EBS volume section and where it says Size(GiB) increase the amount from 8 to 75. It is important to have at least 75 gigs because loading the dataset and supporting libraries take up a large amount of space, not to mention training file checkpoints.

12. For security groups just choose default option.



13. In order to access the server you have to give it a key pair. If you don't have one yet click on Create new key pair and follow the instructions.

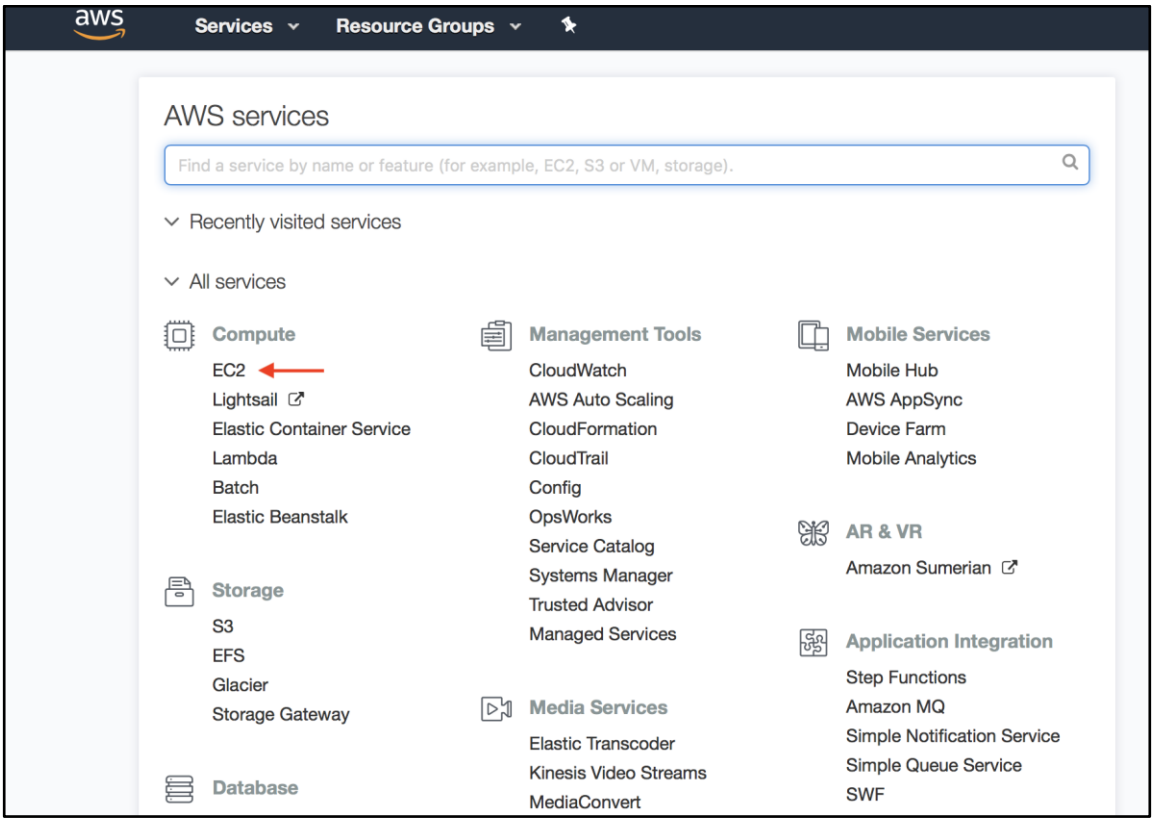




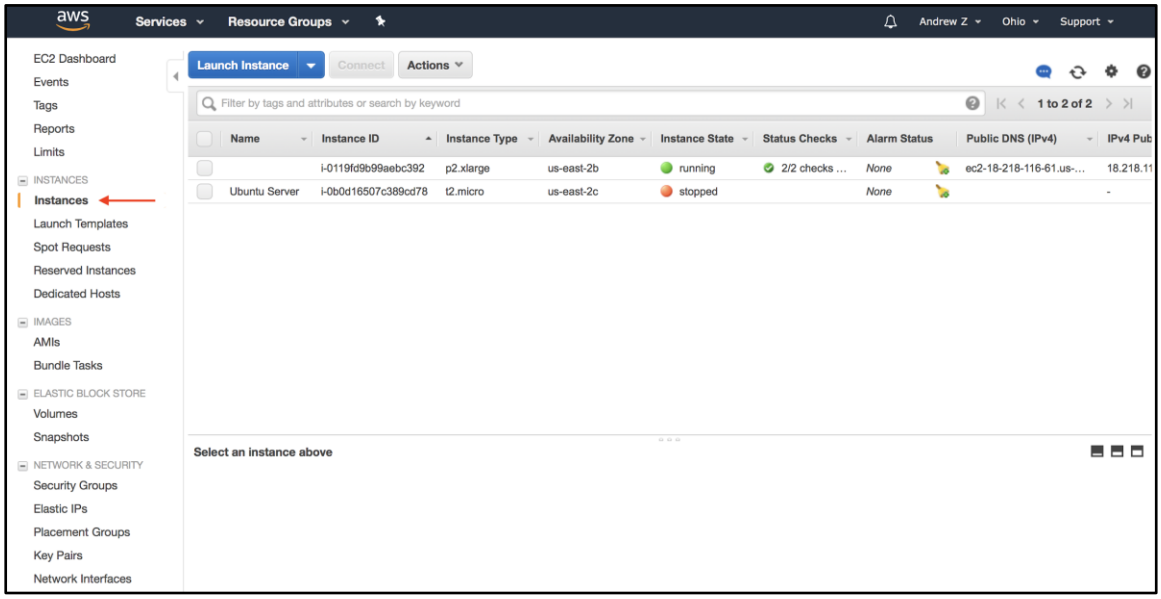
14. Once you make it, it'll automatically save the key to your local desktop. Some different ssh clients like putty need the key in different formats, but there are many instructions online on how to convert it to the specified formats.
15. Once all that is complete go to the very bottom and hit launch in the right corner. It will take a couple of minutes for the request to be fulfilled but after it is you will see the server show up under your EC2 instances.

2.2 On Demand Server

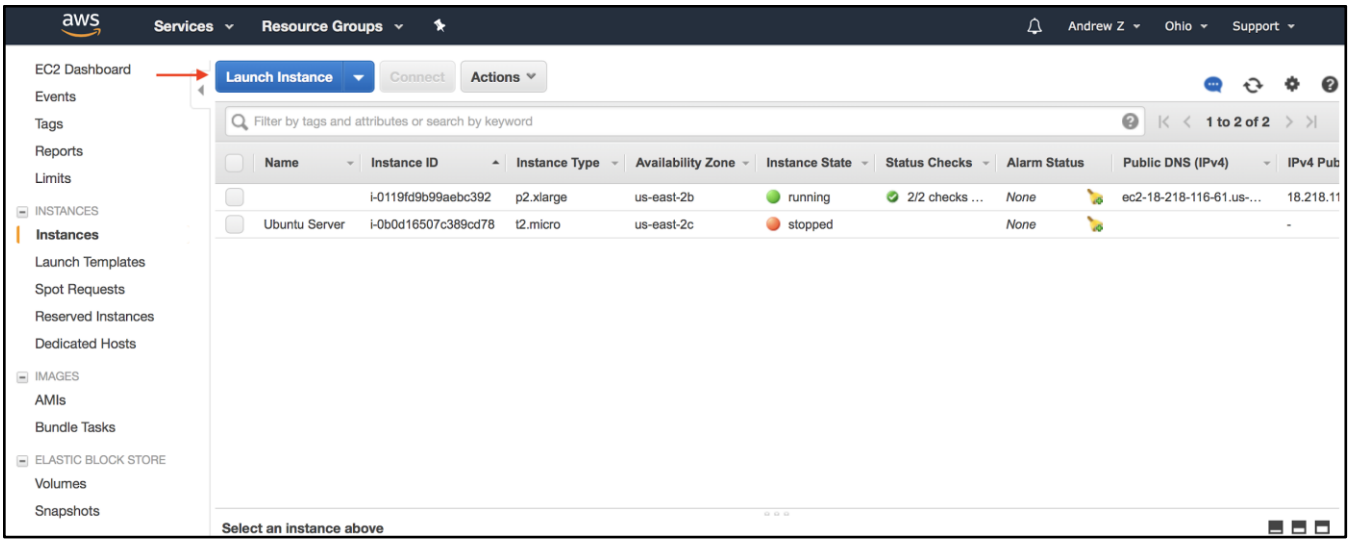
1. Create aws account: https://portal.aws.amazon.com/billing/signup?nc2=h_ct&redirect_url=https%3A%2F%2Faws.amazon.com%2Fregistration-confirmation#/start
2. Go to aws service dashboard. https://us-east-2.console.aws.amazon.com/console/home?region=us-east-2
3. Look under Computer category in all services and select EC2



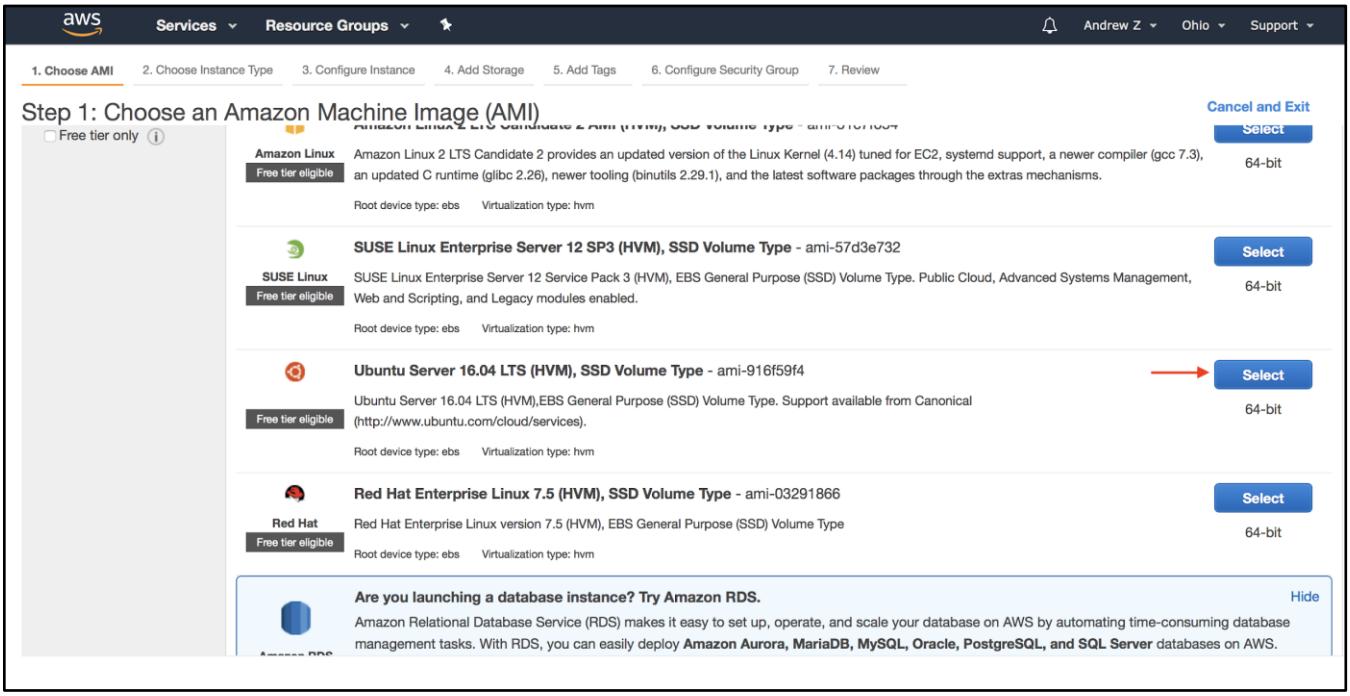
4. Once you get to the EC2 dashboard page, look at the left hand navigation bar and select instances.



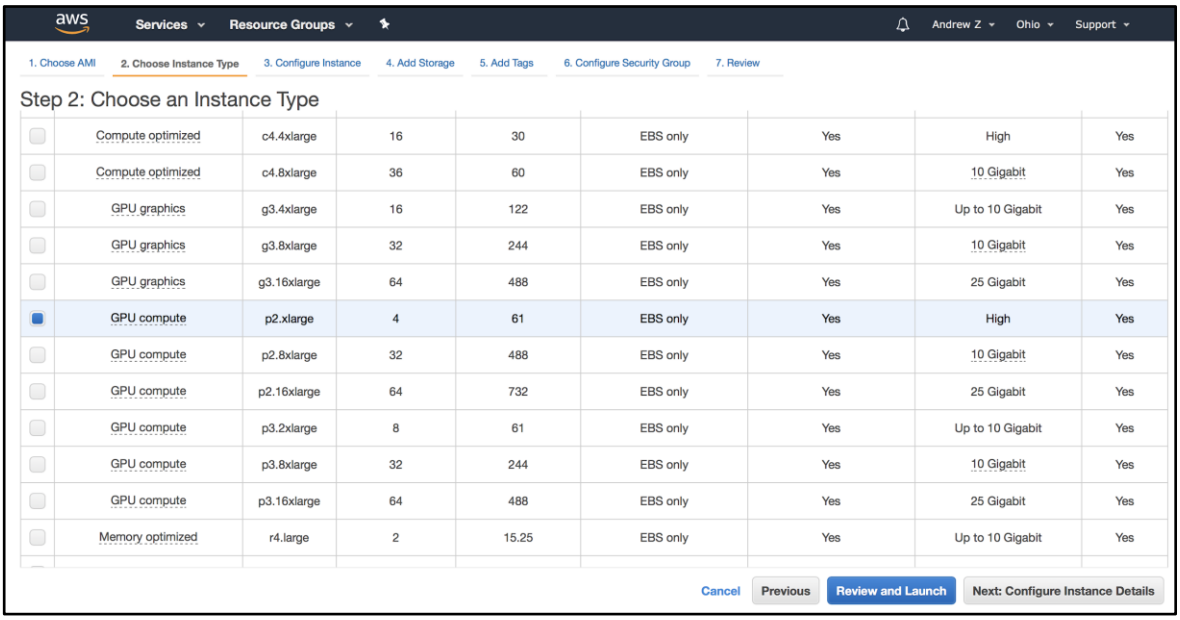
5. Click on launch instance.



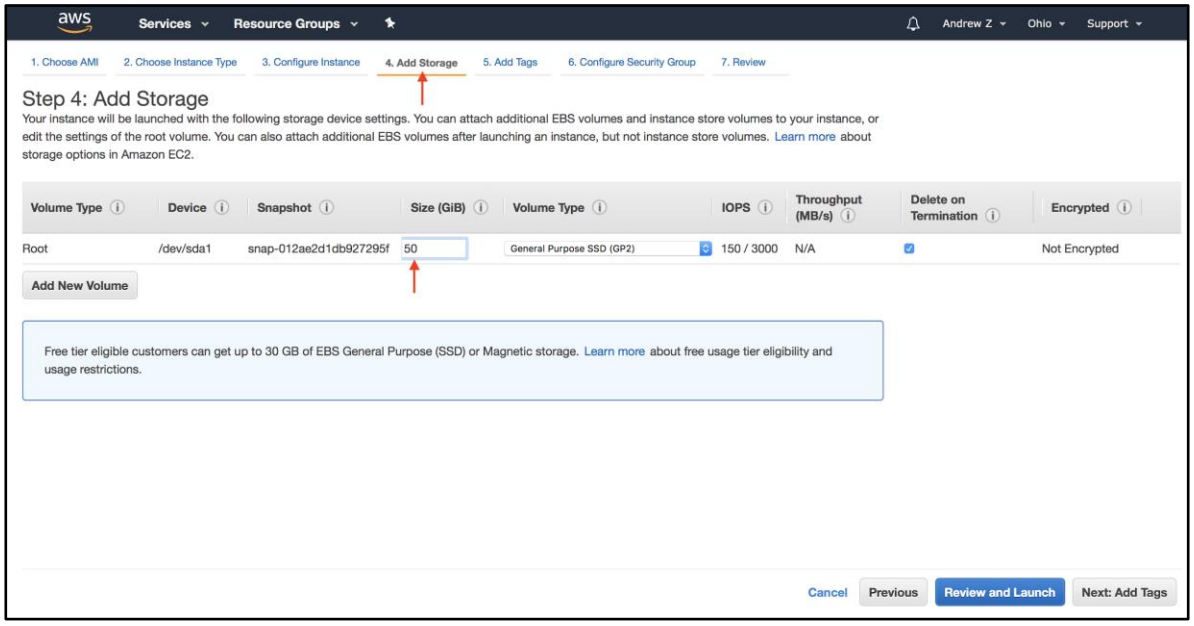
6. At this point select an AMI from the list, in our case Ubuntu 16.04



7. Select instance type. Preferably one with a GPU and in our case a p2xlarge.



8. Next click on add storage and change EBS size to above 50 because server needs to hold a large data set and many files.



9. Everything else should be left to default.
10. Hit launch and review and then again on launch in the bottom right corner.

3. Initial ec2 Server Installation & Configuration

These are the following steps to configure the server in order to run the litter recognition algorithm.

3.1 Installing TensorFlow (GPU) on Ubuntu Server.

Reference: https://www.tensorflow.org/install/install_linux

0) Download installation files

Download and extract the required installation files from Google Drive.
https://drive.google.com/file/d/1Wcko1t2QYRX7DW-Tu2lY4l0-CQgAuqA-/view?usp=sharing

Then, using an FTP client like a FileZilla, move the files into the home directory of the server.

1) Installing GCC

The gcc compiler is required for development using the CUDA Toolkit.

```
      sudo apt-get update && \
      sudo apt-get install build-essential software-properties-common -y && \
      sudo add-apt-repository ppa:ubuntu-toolchain-r/test -y && \
      sudo apt-get update && \
      sudo apt-get install gcc-snapshot -y && \
      sudo apt-get update && \
      sudo apt-get install gcc-6 g++-6 -y && \
      sudo update-alternatives --install /usr/bin/gcc gcc /usr/bin/gcc-6 60 --
slave /usr/bin/g++ g++ /usr/bin/g++-6 && \
      sudo apt-get install gcc-4.8 g++-4.8 -y && \
      sudo update-alternatives --install /usr/bin/gcc gcc /usr/bin/gcc-4.8 60 --
slave /usr/bin/g++ g++ /usr/bin/g++-4.8;
      gcc -v
```

2) Installing CUDA Toolkit 9.0 [Reference]

This toolkit provides the development environment for running high performance GPU-accelerated applications. It includes the NVIDIA drivers needed to interface with the GPU.

```
      sudo apt-get install linux-headers-$(uname -r)

      sudo dpkg -i cuda-repo-ubuntu1604_9.0.176-1_amd64.deb
      sudo apt-key adv --fetch-keys
http://developer.download.nvidia.com/compute/cuda/repos/ubuntu1604/x86_64/7fa2af8
0.pub
      sudo apt-get update
      sudo apt-get install cuda-9-0

      export PATH=/usr/local/cuda-9.0/bin${PATH:+:${PATH}}
```

2.1) Validating CUDA Toolkit 9.0 installation

First reboot the server

```
      sudo reboot
```

Then, enter the following command. This will check the status of the GPU.

```
      nvidia-smi
```

If installed correctly, you will see the following screen below:

```
ubuntu@ip-172-31-19-154:~$ nvidia-smi
Tue May  1 21:02:14 2018
+-----------------------------------------------------------------------------+
| NVIDIA-SMI 390.30                 Driver Version: 390.30                    |
|-------------------------------+----------------------+----------------------+
| GPU  Name        Persistence-M| Bus-Id        Disp.A | Volatile Uncorr. ECC |
| Fan  Temp  Perf  Pwr:Usage/Cap|         Memory-Usage | GPU-Util  Compute M. |
|===============================+======================+======================|
|   0  Tesla K80           Off  | 00000000:00:1E.0 Off |                    0 |
| N/A   52C    P0    59W / 149W |  11216MiB / 11441MiB |      0%      Default |
+-------------------------------+----------------------+----------------------+
```

If you don't see this screen, remove the cuda-9.0 toolkit using the following command, then reinstall it.

```
      sudo apt-get purge $(dpkg -l | awk '$2~/nvidia/ {print $2}')
```

3) Installing cuDNN SDK v7 [Reference]

This is a GPU-accelerated library of primitives for deep neural networks.

```
sudo dpkg -i libcudnn7_7.0.4.31-1+cuda9.0_amd64.deb
sudo dpkg -i libcudnn7-dev_7.0.4.31-1+cuda9.0_amd64.deb
```

4) Installing cudna command-line-tools

```
sudo apt-get install cuda-command-line-tools-9-0
export
LD_LIBRARY_PATH=${LD_LIBRARY_PATH:+${LD_LIBRARY_PATH}:}/usr/local/cuda/extras/CUP
TI/lib64
```

5) Installing NVIDIA TensorRT 3.0

This is used to optimize inference performance.

```
tar xzvf TensorRT-3.0.4.Ubuntu-14.04.5.x86_64.cuda-9.0.cudnn7.0.tar.gz
export LD_LIBRARY_PATH=$LD_LIBRARY_PATH:~/TensorRT-3.0.4/lib
```

6) Setting up the TensorFlow virtual environment

This will create the tensorflow virtual environment under the directory `~/tensorflow`

```
sudo apt-get install python3-pip python3-dev python-virtualenv
virtualenv --system-site-packages -p python3 ~/tensorflow
source ~/tensorflow/bin/activate
```

7) Installing TensorFlow (GPU)

First make sure you are in the tensorflow virtual environment, then run the following

```
easy_install -U pip
pip3 install --upgrade tensorflow-gpu
sudo pip3 install six
```

7.1) Validating the TensorFlow (GPU) installation

First reboot the server.

```
sudo reboot
```

Then, run the following python code:

```
python
import tensorflow as tf
hello = tf.constant('Hello, TensorFlow!')
sess = tf.Session()
print(sess.run(hello))
```

If the system outputs "Hello, TensorFlow!", then you have installed it correctly. Congratulations!

3.2 Installing TensorFlow Object Detection API

Reference:
https://github.com/tensorflow/models/blob/master/research/object_detection/g3doc/installation.md

1) Activate your TensorFlow environment.

```
source ~/tensorflow/bin/activate
```

1.1) You should now see something similar to the following snippet:

```
(tensorflow) ubuntu@<ip-address-of-server>: ~$
```

2) Install the necessary Python dependencies.

```
pip3 install pillow
pip3 install lxml
pip3 install jupyter
pip3 install matplotlib
```

3) Install the updated protobuf zip.

3.1) Download the Python protobuf zip folder from the Google protobuf releases webpage. All protobuf releases are located at the following web address: https://github.com/google/protobuf/releases.

```
cd
wget https://github.com/google/protobuf/releases/download/v3.5.0/protobuf-
```

```
python-3.5.0.zip
```

3.2) Unzip the downloaded folder, creating the "protobuf-3.5.0" directory in your current directory.

```
sudo apt install unzip  # install unzip
unzip protobuf-python-3.5.0.zip
```

3.3) Install protobuf.

```
cd ~/protobuf-3.5.0
sudo ./configure
sudo make check
sudo make install

# export to the correct library path
export LD_LIBRARY_PATH=/usr/local/lib
```

3.3.1) Verify protobuf 3.5.0 is currently installed.

```
protoc --version

# expected output
libprotoc 3.5.0
```

4) Download our models directory from using the following link. Do not unzip the file:

https://drive.google.com/file/d/1z-PaHvQ3UcjQJRv-3HrVgQudpgDnBtok/view?usp=sharing

4.1) Transfer zip file into the server's home directory using the FTP client you used transferring the dependency files in step 0 of section 3.1.

5.) Use the following command to unzip the file.

```
unzip models.zip
```

This results in a newly created directory named "models" in your home directory.

4. Training a Custom Dataset

Refer to this tutorial:
https://pythonprogramming.net/introduction-use-tensorflow-object-detection-api-tutorial/

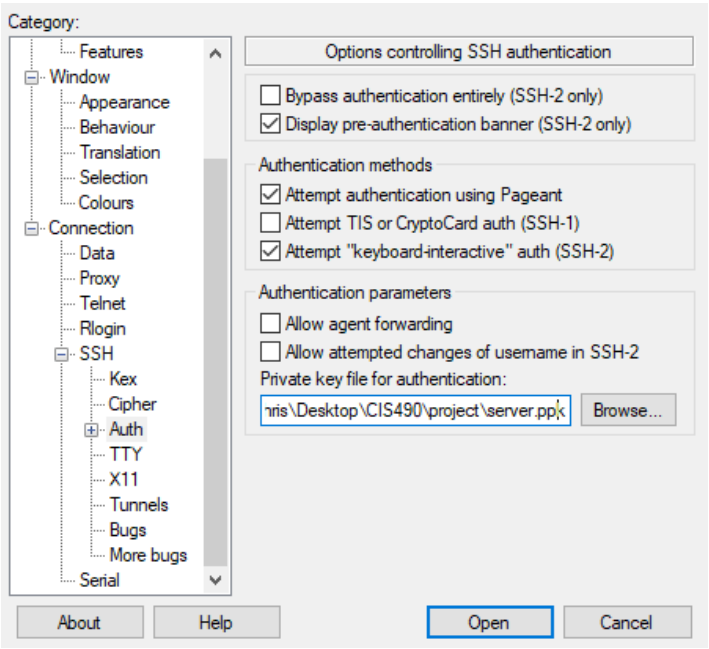
5. Accessing Jupyter Notebook

5.1 Windows

For the purposes of this project, Putty was used on Windows computers to interface the ec2 server.

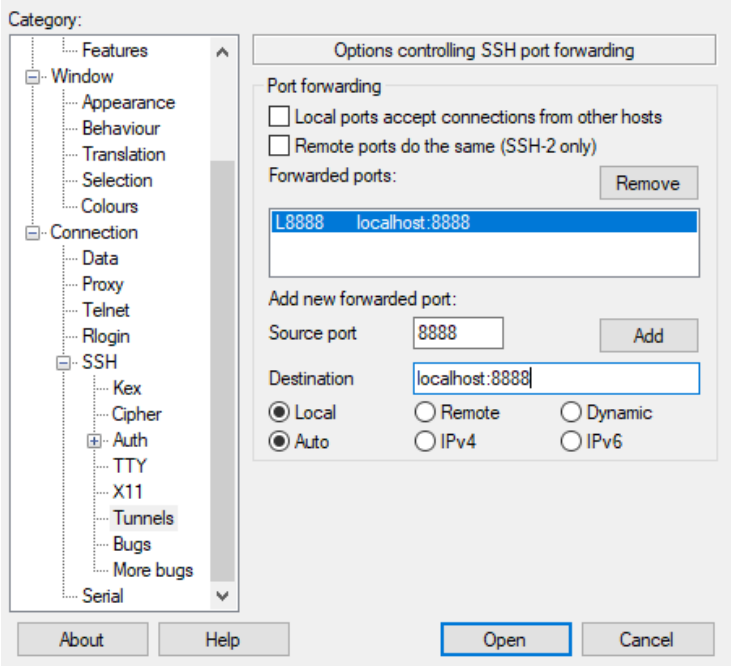
1. Download and install Putty from https://www.putty.org/

2. Load in the private key under [Connection > SSH > Auth]
    a. Click “browse” and select your private key file



3. Setup SSH tunneling under [Connection > SSH > Tunnels]. Enter these values:

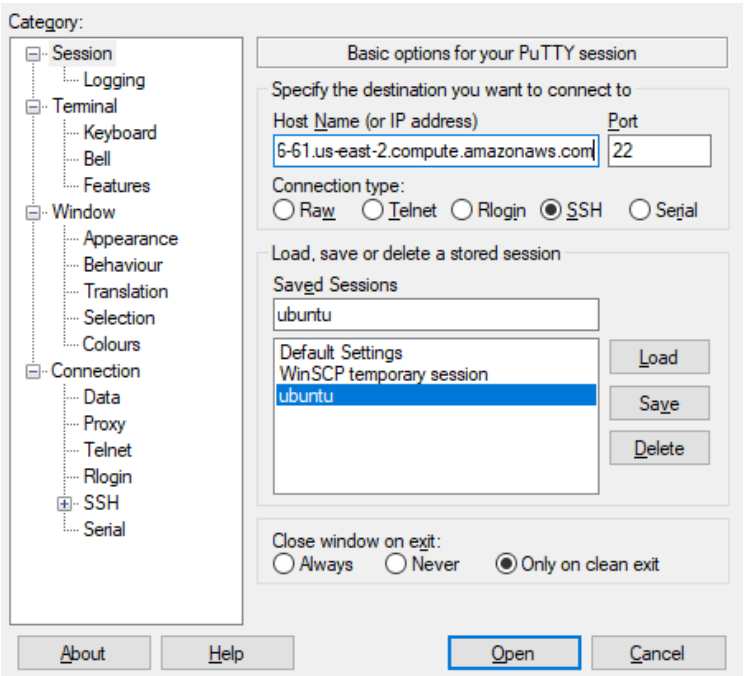
```
Source Port:    8888
Destination:    localhost:8888
```



This is needed for jupyter notebook to work correctly.

4. Enter the server connection details under [Session]

IP: ec2-18-218-116-61.us-east-2.compute.amazonaws.com
Port: 22
Connection Type: SSH



5. Save the session and click open to login to the server.

6. Login as **Ubuntu**.

5.2 Mac

For the purposes of this project, Terminal, a native Mac application, was used on Mac computers to interface the ec2 server.

1. In the Terminal application, change directories to the location of the private key file that you created when you launched the instance. This private key file will have the format: *filename.pem*. Execute the following command into the Terminal window:

```
cd path/to/file.pem
```

2. Use the **chmod** command to make sure that your private key file isn't publicly viewable. For example, if the name of your private key file is my-key-pair.pem, use the following command:

```
chmod 400 /path/my-key-pair.pem
```

3. Use the **ssh** command to connect to the instance. You specify the private key (.pem) file and *user_name@public_dns_name*. For example, if you used an Amazon Linux AMI, user_name is ec2-user. If you used Ubuntu, user_name is ubuntu. Replace <ec2-domain> with your actual domain address.

```
ssh -i "FixItServer.pem" -L 8157:127.0.0.1:8888 user_name@<public_dns_name>
```

The first time you login, you should see the following response:

```
The authenticity of host 'ec2-198-51-100-1.compute-1.amazonaws.com
(10.254.142.33)'
can't be established.
RSA key fingerprint is
1f:51:ae:28:bf:89:e9:d8:1f:25:5d:37:2d:7d:b8:ca:9f:f5:f1:6f.
Are you sure you want to continue connecting (yes/no)?
```

Type **yes** to connect. After your initial login, after you execute the ssh command, you will be automatically logged into the server.

5.3 Initial configuration

1. Activate Tensorflow environment by using the following command:

```
source ~/tensorflow/bin/activate
```

2. Change directories to the models/research directory.

```
cd ~/models/research
```

3. Compile the protoc library. Execute the following command:

```
protoc object_detection/protos/*.proto --python_out=.
```

4. Export the appropriate Python path. Execute the following command:

```
export PYTHONPATH=$PYTHONPATH:`pwd`:`pwd`/slim
```

5.4 Using Jupyter Notebook

The Jupyter Notebook is an open-source web application that allows you to create and share documents that contain live code, equations, visualizations and narrative text. This application will be used to execute the algorithm on chosen test images. These test images are located in the ~/models/research/object_detection/test_images folder.

1. Change directories models/research/object_detection by using the following command:

```
cd ~/models/research/object_detection
```

2. Run Jupyter Notebook using the following command:

```
jupyter-notebook
```

You should see the following results:

```
Serving notebooks from local directory:
/home/ubuntu/models/research/object_detection
[I 22:00:04.373 NotebookApp] 0 active kernels
[I 22:00:04.373 NotebookApp] The Jupyter Notebook is running at:
[I 22:00:04.373 NotebookApp]
http://localhost:8888/?token=dec0e2a8d30add83c31c735213336503524e16e9f952b5b5
[I 22:00:04.373 NotebookApp] Use Control-C to stop this server and shut down all
kernels (twice to skip confirmation).
[W 22:00:04.373 NotebookApp] No web browser found: could not locate runnable
browser.
```

```
[C 22:00:04.373 NotebookApp]

    Copy/paste this URL into your browser when you connect for the first time,
    to login with a token:

http://localhost:8888/?token=dec0e2a8d30add83c31c735213336503524e16e9f952b5b5
```

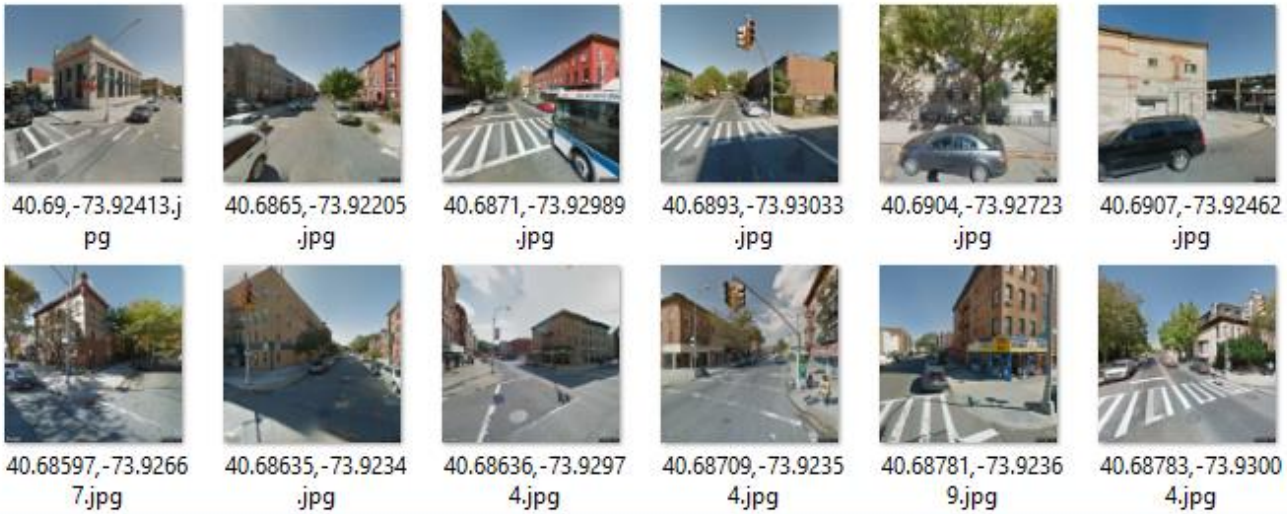
3. In any web browser type **localhost:8157** to access the Jupyter Notebook interface. Copy the token string (i.e. the red bolded line of text bolded in the above snippet) into the password textbox to login.

6. Future Use

6.1 How to gather images for Data Set

To gather images of litter for the data set, we have created a python script tool that pulls google street images along a given path specified by a .gpx file. The resolution of these images pulled are 640x640.

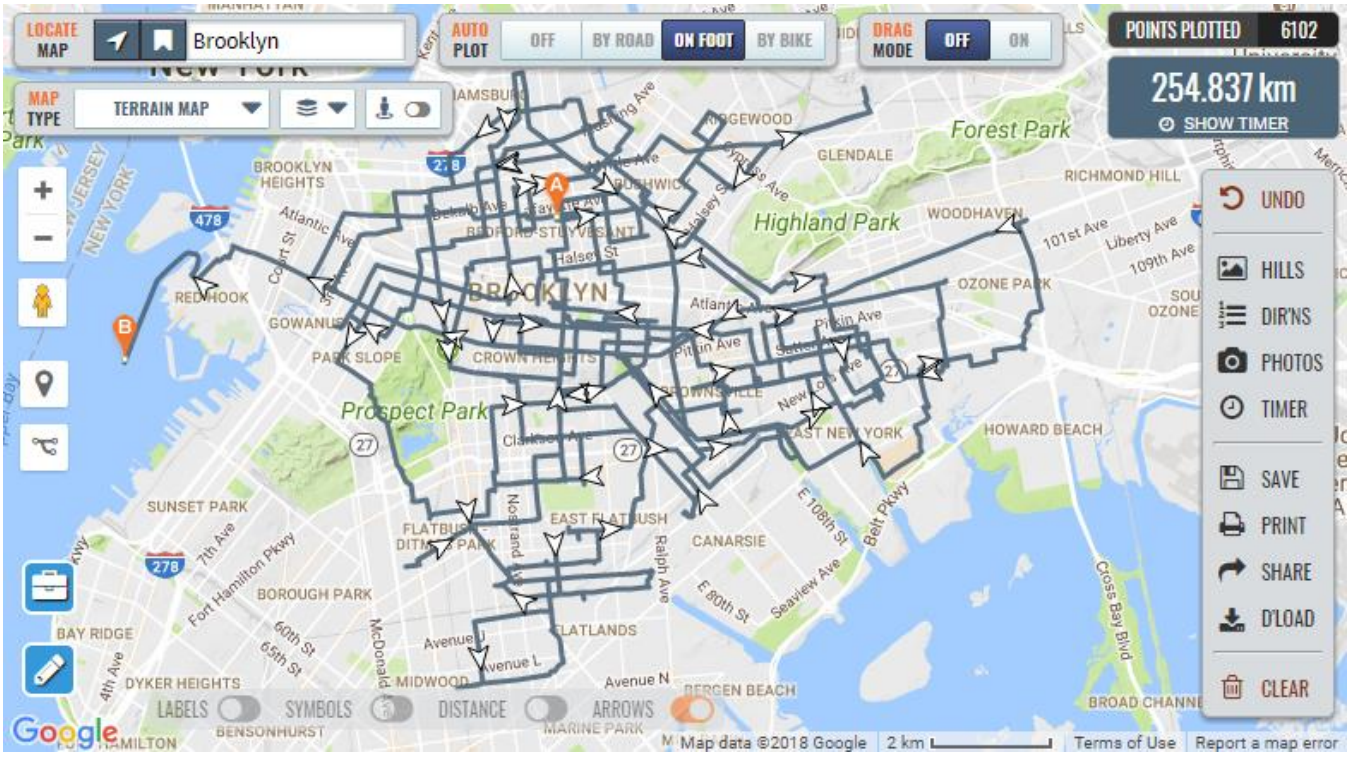
Download link:
https://github.com/isaychris/gpx-streetview-imager



Prerequisites:

- Python 2
- .gpx file (instructions below)
- Google API key from https://developers.google.com/maps/documentation/streetview/.

Creating a Path:



1. Go to https://www.plotaroute.com/routeplanner
2. Enter the location you want to take street view images from.
3. Change Auto Pilot to 'On Foot'.
4. Enable street view Overlay.
5. Create your desired route along the blue street view paths. The number of points plotted displayed on the upper right corner is how many images the script will pull.
6. Download and save as 'File type: GPX, File Format: GPX, GPX TYPE: Track'.

Running the script:

1. Put your .gpx file in the same directory as the script.
2. Open the script and change the API_KEY, SAVE_PATH, and GPX_FILE variables.
3. Run the script by typing:

```
python street.py
```

After running the script:

https://github.com/isaychris/gpx-streetview-imager/tree/master/other

In the link provided above, there are two python scripts you can run after gathering the images.

You may have noticed there are several blank grey images in your folder. This is because the script couldn't find the google street data for that particular coordinate. To remove these blank grey images, use the cleaner.py script.

```
python cleaner.py
```

Another thing you may want to do is rename these images. To simply rename the files in bulk given a particular naming format like image001.jpg, images002.jpg, ect …, use the renamer.py script.

```
python renamer.py
```

Before any of these scripts can be ran, edit in your image directory, then simply run.

6.2 How to label images for Data Set

In order to label the images in your data set, a image labeling software like **LabelImg** is required. The software is compatible with windows, linux, and *mac.

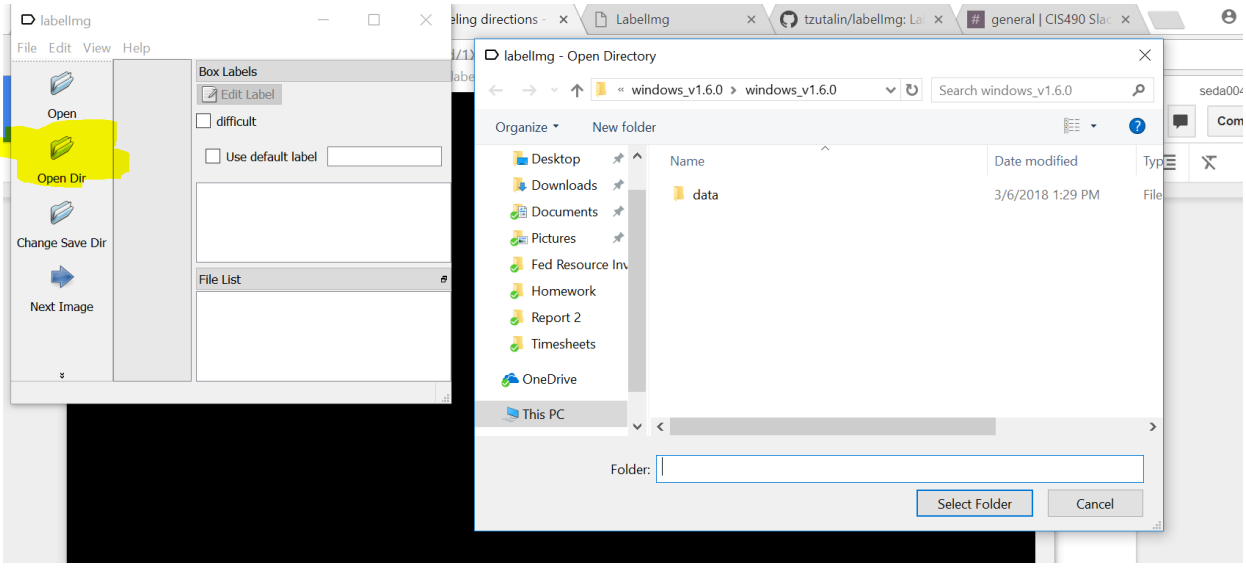
Download Link:

- https://github.com/tzutalin/labelImg

**If you wish to run the software on a mac, you will have to compile the software from source. Because of this, we recommend installing the windows version.*

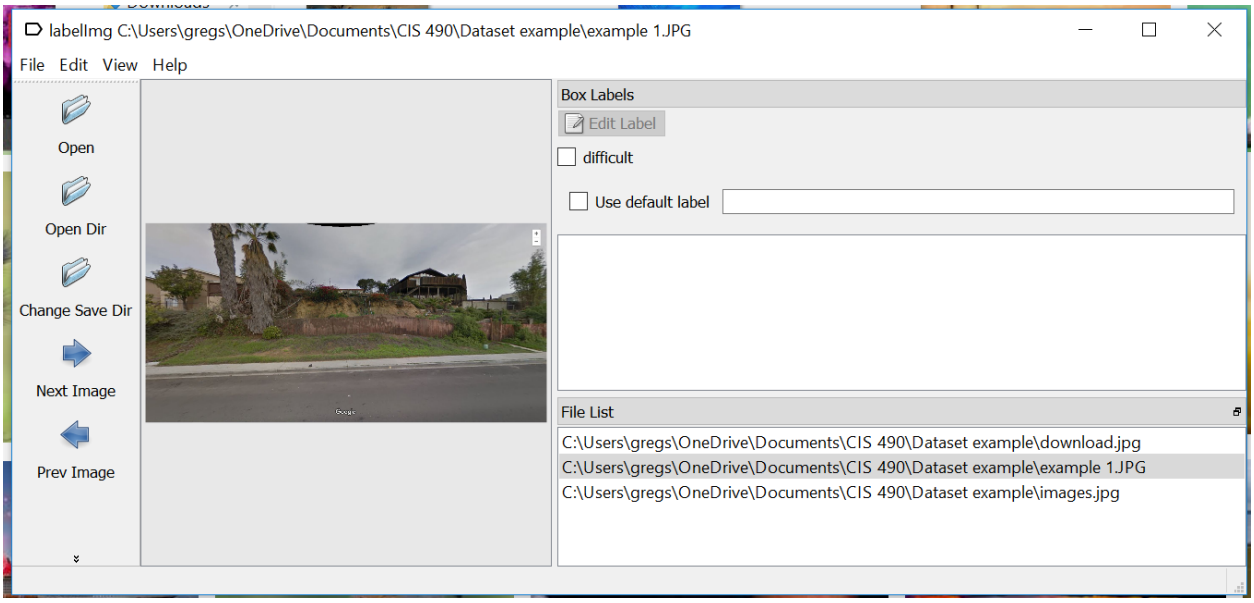
How to use the software:

1. Launch the application
2. Open the directory to your image dataset by clicking on "Open Dir". Then select the folder with the images you want to label.

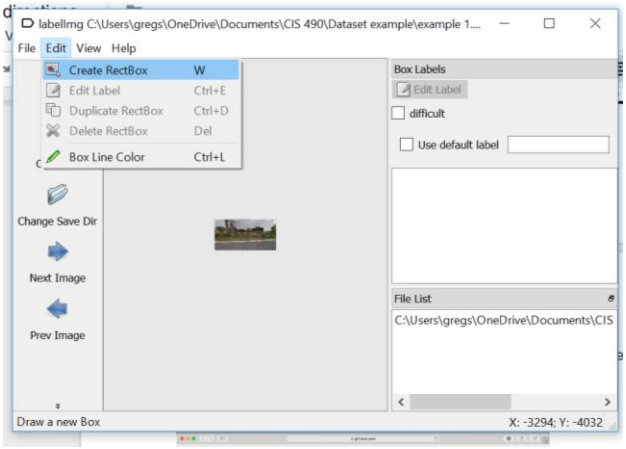


Your list of images will now show on the right side of the application.

3. To navigate between the different images in your dataset, double click on each file name under ‘File List’ on the bottom right corner.

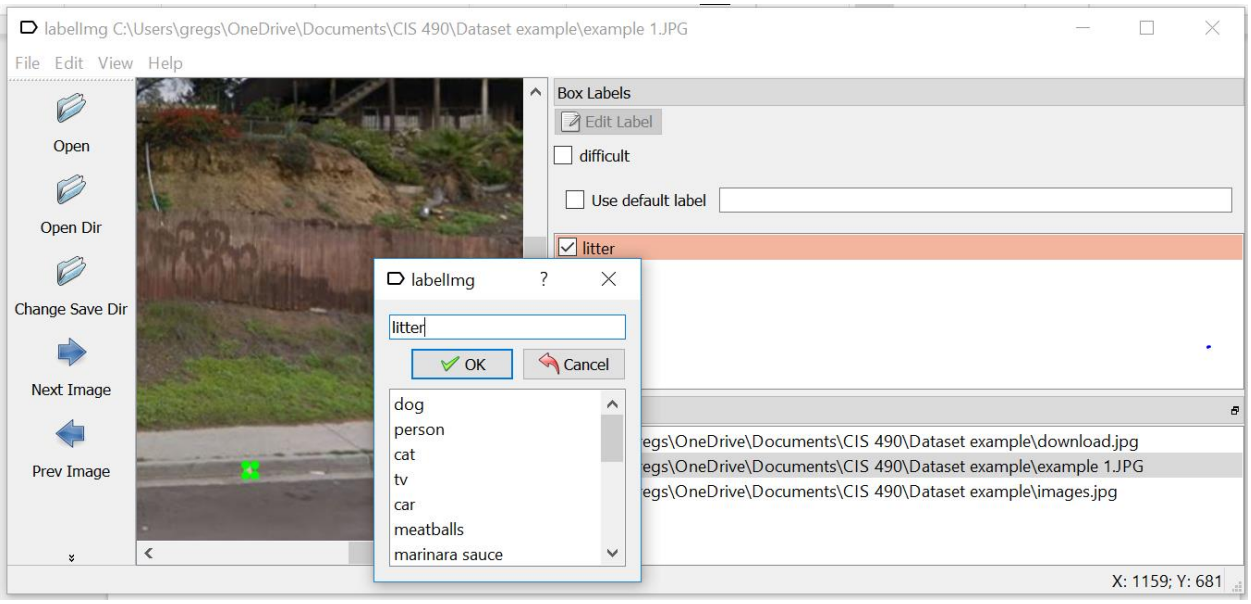


4. Select an image. To annotate the image, click on Edit -> 'Create RectBox'.(shortcut ‘W’)



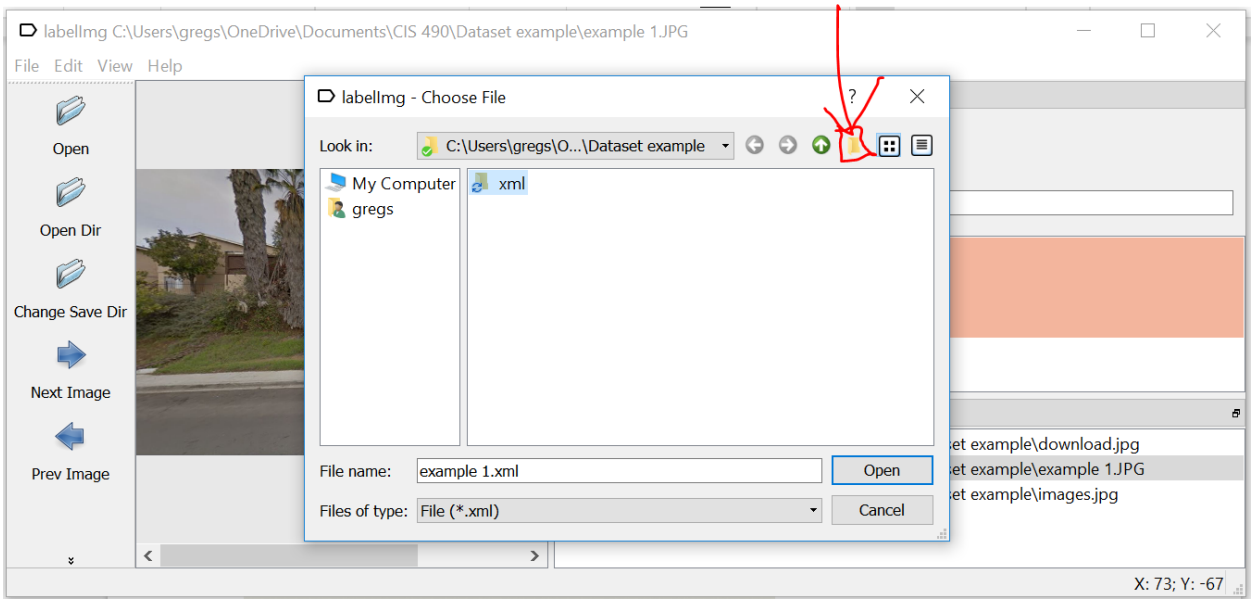
5. Locate the litter objects in the image, then click and release the left mouse button to draw a rectangle over the object.

Try to be as precise as possible with the boxing even though the litter might be really small.



6. Next type in 'litter' as the label name. (all lowercase)

7. Save the image. If done correctly, it should produce an .xml file with the same name as the image. Go to Edit -> 'save as' and create a new folder (click the marked icon) in your dataset folder called 'xml'. Save all the labeled images in there.



8. Repeat steps for every image in your dataset folder

6.3 How to convert the dataset into TFrecord.

Once the images in the dataset have been labeled, it must be converted to a format tensorflow can read called a TFrecord.

This is done by running two scripts that first converts the .xml files into a .csv file, then converting the .csv file into a TFrecord file.

Before that can be done, the dataset must first be split into a training and test sets. For our project, we split 80% into training, and 20% into testing.

Instructions:

1) Login to the server, then make a directory called "Object-Detection" and structure it as the following:

Object-Detection
- training/
- data/
- images/
-- test/
-- train/

2. Download these two files and place in into the root of the directory.

- xml_to_csv.py = [Download Link]
- generate_tfrecord.py = [Download Link]

2) Split the dataset into training and testing sets.

- Move the images into images/, then move 80% of .xml files into train/ and 20% into test/.

3) Create the .csv files for training and testing.

- The created csv files will be placed in data/

```
cd object-detection
python3 xml_to_csv.py
```

4) Convert the .csv files for training and testing into TFRecords.

- The created TFrecords will be placed in data/

```
source ~/tensorflow/bin/activate
python3 generate_tfrecord.py --csv_input=data/train_labels.csv --
output_path=data/train.record
python3 generate_tfrecord.py --csv_input=data/test_labels.csv --
output_path=data/test.record
```