1 Installation

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This is a step-by-step tutorial/guide to setting up and using TensorFlow’s Object Detection API to perform, namely, object detection in images/video.

The software tools which we shall use throughout this tutorial are listed in the table below:

<table>
<thead>
<tr>
<th>Target Software versions</th>
<th>OS</th>
<th>Windows, Linux*</th>
</tr>
</thead>
<tbody>
<tr>
<td>Python</td>
<td>3.6</td>
<td></td>
</tr>
<tr>
<td>TensorFlow</td>
<td>1.9</td>
<td></td>
</tr>
<tr>
<td>CUDA Toolkit</td>
<td>v9.0</td>
<td></td>
</tr>
<tr>
<td>CuDNN</td>
<td>v7.0.5</td>
<td></td>
</tr>
<tr>
<td>Anaconda</td>
<td>Python 3.7 (Optional)</td>
<td></td>
</tr>
</tbody>
</table>

* Even though this tutorial is mostly based (and properly tested) on Windows 10, information is also provided for Linux systems.
1.1 General Remarks

- There are two different variations of TensorFlow that you might wish to install, depending on whether you would like TensorFlow to run on your CPU or GPU, namely TensorFlow CPU and TensorFlow GPU. I will proceed to document both and you can choose which one you wish to install.

- If you wish to install both TensorFlow variants on your machine, ideally you should install each variant under a different (virtual) environment. If you attempt to install both TensorFlow CPU and TensorFlow GPU, without making use of virtual environments, you will either end up failing, or when we later start running code there will always be an uncertainty as to which variant is being used to execute your code.

- To ensure that we have no package conflicts and/or that we can install several different versions/variants of TensorFlow (e.g. CPU and GPU), it is generally recommended to use a virtual environment of some sort. For the purposes of this tutorial we will be creating and managing our virtual environments using Anaconda, but you are welcome to use the virtual environment manager of your choice (e.g. virtualenv).

1.2 Install Anaconda Python 3.7 (Optional)

Although having Anaconda is not a requirement in order to install and use TensorFlow, I suggest doing so, due to it’s intuitive way of managing packages and setting up new virtual environments. Anaconda is a pretty useful tool, not only for working with TensorFlow, but in general for anyone working in Python, so if you haven’t had a chance to work with it, now is a good chance.

Windows

- Go to https://www.anaconda.com/download/

- Download Anaconda Python 3.7 version for Windows

- Run the downloaded executable (.exe) file to begin the installation. See here for more details.
• (Optional) In the next step, check the box “Add Anaconda to my PATH environment variable”. This will make Anaconda your default Python distribution, which should ensure that you have the same default Python distribution across all editors.

Linux
• Go to https://www.anaconda.com/download/
• Download Anaconda Python 3.7 version for Linux
• Run the downloaded bash script (.sh) file to begin the installation. See here for more details.
• When prompted with the question “Do you wish the installer to prepend the Anaconda<2 or 3> install location to PATH in your /home/<user>/.bashrc ?”, answer “Yes”. If you enter “No”, you must manually add the path to Anaconda or conda will not work.

1.3 TensorFlow Installation

As mentioned in the Remarks section, there exist two generic variants of TensorFlow, which utilise different hardware on your computer to run their computationally heavy Machine Learning algorithms.

1. The simplest to install, but also in most cases the slowest in terms of performance, is TensorFlow CPU, which runs directly on the CPU of your machine.

2. Alternatively, if you own a (compatible) Nvidia graphics card, you can take advantage of the available CUDA cores to speed up the computations performed by Tensorflow, in which case you should follow the guidelines for installing TensorFlow GPU.

1.3.1 TensorFlow CPU

Getting setup with an installation of TensorFlow CPU can be done in 3 simple steps.

1.3.1.1 Create a new Conda virtual environment (Optional)

• Open a new Anaconda/Command Prompt window
• Type the following command:

```
conda create -n tensorflow_cpu pip python=3.6
```
• The above will create a new virtual environment with name tensorflow_cpu
• Now lets activate the newly created virtual environment by running the following in the Anaconda Prompt window:

```
activate tensorflow_cpu
```

Once you have activated your virtual environment, the name of the environment should be displayed within brackets at the begining of your cmd path specifier, e.g.:

```
(tensorflow_cpu) C:\Users\sgvladi>
```
1.3.1.2 Install TensorFlow CPU for Python

- Open a new Anaconda/Command Prompt window and activate the `tensorflow_cpu` environment (if you have not done so already)
- Once open, type the following on the command line:

  ```bash
  pip install --ignore-installed --upgrade tensorflow==1.9
  ```
- Wait for the installation to finish

1.3.1.3 Test your Installation

- Open a new Anaconda/Command Prompt window and activate the `tensorflow_cpu` environment (if you have not done so already)
- Start a new Python interpreter session by running:

  ```python
  python
  ```
- Once the interpreter opens up, type:

  ```python
  >>> import tensorflow as tf
  ```
- If the above code shows an error, then check to make sure you have activated the `tensorflow_cpu` environment and that `tensorflow_cpu` was successfully installed within it in the previous step.
- Then run the following:

  ```python
  >>> hello = tf.constant('Hello, TensorFlow!')
  >>> sess = tf.Session()
  ```
- Once the above is run, if you see a print-out similar (or identical) to the one below, it means that you could benefit from installing TensorFlow by building the sources that correspond to you specific CPU. Everything should still run as normal, just slower than if you had built TensorFlow from source.

  ```text
  → T:\src\github\tensorflow\tensorflow\core\platform\cpu_feature_guard.
  → cc:141] Your CPU supports instructions that this TensorFlow binary was
  → not compiled to use: AVX2
  ```
- Finally, for the sake of completing the test as described by TensorFlow themselves (see here), let’s run the following:

  ```python
  >>> print(sess.run(hello))
  b'Hello, TensorFlow!'
  ```

1.3.2 TensorFlow GPU

The installation of TensorFlow GPU is slightly more involved than that of TensorFlow CPU, mainly due to the need of installing the relevant Graphics and CUDA drivers. There’s a nice Youtube tutorial (see here), explaining how to install TensorFlow GPU. Although it describes different versions of the relevant components (including TensorFlow itself), the installation steps are generally the same with this tutorial.

Before proceeding to install TensorFlow GPU, you need to make sure that your system can satisfy the following requirements:
1.3.2.1 Install CUDA Toolkit

Windows
Follow this link to download and install CUDA Toolkit v9.0.

Linux
Follow this link to download and install CUDA Toolkit v9.0 for your Linux distribution.

1.3.2.2 Install CUDNN

Windows
- Go to https://developer.nvidia.com/rdp/cudnn-download
- Create a user profile if needed and log in
- Select cuDNN v7.0.5 (Feb 28, 2018), for CUDA 9.0
- Download cuDNN v7.0.5 Library for Windows 10
  - Extract the contents of the zip file (i.e. the folder named cuda) inside <INSTALL_PATH>\NVIDIA GPU Computing Toolkit\CUDA\v9.0\, where <INSTALL_PATH> points to the installation directory specified during the installation of the CUDA Toolkit. By default <INSTALL_PATH> = C:\Program Files.

Linux
- Go to https://developer.nvidia.com/rdp/cudnn-download
- Create a user profile if needed and log in
- Select cuDNN v7.0.5 (Feb 28, 2018), for CUDA 9.0
- Download cuDNN v7.0.5 Library for Linux
  - Follow the instructions under Section 2.3.1 of the CuDNN Installation Guide to install CuDNN.

1.3.2.3 Environment Setup

Windows
- Go to Start and Search “environment variables”
- Click the Environment Variables button
- Click on the Path system variable and select edit
- Add the following paths:
  - <INSTALL_PATH>\NVIDIA GPU Computing Toolkit\CUDA\v9.0\bin
  - <INSTALL_PATH>\NVIDIA GPU Computing Toolkit\CUDA\v9.0\libnvcv
TF setup Documentation

- `<INSTALL_PATH>NVIDIA GPU Computing Toolkit\CUDA\v9.0\extras\CUPTI\libx64`
- `<INSTALL_PATH>NVIDIA GPU Computing Toolkit\CUDA\v9.0\cuda\bin`

Linux

As per Section 7.1.1 of the CUDA Installation Guide for Linux, append the following lines to `~/.bashrc`:

```bash
# CUDA related exports
export PATH=/usr/local/cuda-9.0/bin$({PATH:+:$PATH})
export LD_LIBRARY_PATH=/usr/local/cuda-9.0/lib64$({LD_LIBRARY_PATH:+:$LD_LIBRARY_PATH})
```

1.3.2.4 Update your GPU drivers (Optional)

If during the installation of the CUDA Toolkit (see Install CUDA Toolkit) you selected the Express Installation option, then your GPU drivers will have been overwritten by those that come bundled with the CUDA toolkit. These drivers are typically NOT the latest drivers and, thus, you may wish to update your drivers.

- Select your GPU version to download
- Install the driver for your chosen OS

1.3.2.5 Create a new Conda virtual environment

- Open a new Anaconda/Command Prompt window
- Type the following command:

  ```bash
  conda create -n tensorflow_gpu pip python=3.6
  ```

- The above will create a new virtual environment with name `tensorflow_gpu`
- Now let's activate the newly created virtual environment by running the following in the Anaconda Prompt window:

  ```bash
  activate tensorflow_gpu
  ```

Once you have activated your virtual environment, the name of the environment should be displayed within brackets at the beginning of your cmd path specifier, e.g.:

```
(tensorflow_gpu) C:\Users\sglvladi>
```

1.3.2.6 Install TensorFlow GPU for Python

- Open a new Anaconda/Command Prompt window and activate the `tensorflow_gpu` environment (if you have not done so already)
- Once open, type the following on the command line:

  ```bash
  pip install --ignore-installed --upgrade tensorflow-gpu==1.9
  ```

- Wait for the installation to finish

1.3. TensorFlow Installation
1.3.2.7 Test your Installation

- Open a new Anaconda/Command Prompt window and activate the tensorflow_gpu environment (if you have not done so already)

- Start a new Python interpreter session by running:

```
python
```

- Once the interpreter opens up, type:

```
>>> import tensorflow as tf
```

- If the above code shows an error, then check to make sure you have activated the tensorflow_gpu environment and that tensorflow_gpu was successfully installed within it in the previous step.

- Then run the following:

```
>>> hello = tf.constant('Hello, TensorFlow!')
>>> sess = tf.Session()
```

- Once the above is run, you should see a print-out similar (but not identical) to the one bellow:

```
2019-02-28 06:56:43.617192: I ˓→ T:\src\github\tensorflow\tensorflow\core\platform\cpu_feature_guard.˓→ cc:140] Your CPU supports instructions that this TensorFlow binary was ˓→ not compiled to use: AVX2
2019-02-28 06:56:43.792865: I ˓→ T:\src\github\tensorflow\tensorflow\core\common_runtime\gpu\gpu_device.˓→ cc:1356] Found device 0 with properties:
name: GeForce GTX 1080 major: 6 minor: 1 memoryClockRate(GHz): 1.7335
pciBusID: 0000:01:00.0 totalMemory: 8.00GiB freeMemory: 6.61GiB
2019-02-28 06:56:43.799610: I ˓→ T:\src\github\tensorflow\tensorflow\core\common_runtime\gpu\gpu_device.˓→ cc:1435] Adding visible gpu devices: 0
2019-02-28 06:56:44.338418: I ˓→ T:\src\github\tensorflow\tensorflow\core\common_runtime\gpu\gpu_device.˓→ cc:923] Device interconnect StreamExecutor with strength 1 edge matrix:
2019-02-28 06:56:44.348418: I ˓→ T:\src\github\tensorflow\tensorflow\core\common_runtime\gpu\gpu_device.˓→ cc:929] 0
2019-02-28 06:56:44.351039: I ˓→ T:\src\github\tensorflow\tensorflow\core\common_runtime\gpu\gpu_device.˓→ cc:942] 0: N
2019-02-28 06:56:44.352873: I ˓→ T:\src\github\tensorflow\tensorflow\core\common_runtime\gpu\gpu_device.˓→ cc:1053] Created TensorFlow device (/job:localhost/replica:0/task:0/device:GPU:0 with 6387 MB memory) -> physical GPU (device: 0, name:
GeForce GTX 1080, pci bus id: 0000:01:00.0, compute capability: 6.1)
```

- Finally, for the sake of completing the test as described by TensorFlow themselves (see here), let’s run the following:

```
>>> print(sess.run(hello))
b'Hello, TensorFlow!'
```
1.4 TensorFlow Models Installation

Now that you have installed TensorFlow, it is time to install the models used by TensorFlow to do its magic.

1.4.1 Install Prerequisites

Building on the assumption that you have just created your new virtual environment (whether that’s `tensorflow_cpu`, `tensorflow_gpu` or whatever other name you might have used), there are some packages which need to be installed before installing the models.

<table>
<thead>
<tr>
<th>Prerequisite packages</th>
</tr>
</thead>
<tbody>
<tr>
<td>Name</td>
</tr>
<tr>
<td>pillow</td>
</tr>
<tr>
<td>lxml</td>
</tr>
<tr>
<td>jupyter</td>
</tr>
<tr>
<td>matplotlib</td>
</tr>
<tr>
<td>opencv</td>
</tr>
</tbody>
</table>

The packages can be installed using `conda` by running:

```shell
conda install <package_name>(=<version>), <package_name>(=<version>), ..., <package_name>(=<version>)
```

where `<package_name>` can be replaced with the name of the package, and optionally the package version can be specified by adding the optional specifier `=<version>` after `<package_name>`. For example, to simply install all packages at their latest versions you can run:

```shell
conda install pillow, lxml, jupyter, matplotlib, opencv, cython
```

Alternatively, if you don’t want to use Anaconda you can install the packages using `pip`:

```shell
pip install <package_name>(==<version>) <package_name>(==<version>) ... <package_name>(==<version>)
```

but you will need to install `opencv-python` instead of `opencv`.

1.4.2 Downloading the TensorFlow Models

- Create a new folder under a path of your choice and name it `TensorFlow`. (e.g. `C:\Users\sgvladi\Documents\TensorFlow`).
- From your `Anaconda/Command Prompt` `cd` into the `TensorFlow` directory.
- To download the models you can either use Git to clone the TensorFlow Models repo inside the `TensorFlow` folder, or you can simply download it as a ZIP and extract it’s contents inside the `TensorFlow` folder. To keep things consistent, in the latter case you will have to rename the extracted folder `models-master` to `models`.¹
- You should now have a single folder named `models` under your `TensorFlow` folder, which contains another 4 folders as such:

¹ The latest repo commit when writing this tutorial is `4b566d4`. 
1.4.3 Protobuf Installation/Compilation

The Tensorflow Object Detection API uses Protobufs to configure model and training parameters. Before the framework can be used, the Protobuf libraries must be downloaded and compiled.

This should be done as follows:

- Head to the protoc releases page
- Download the latest *-win32.zip release (e.g. protoc-3.5.1-win32.zip)
- Create a folder in C:\Program Files and name it Google Protobuf.
- Extract the contents of the downloaded *-win32.zip, inside C:\Program Files\Google Protobuf
- Add C:\Program Files\Google Protobuf\bin to your Path environment variable (see Environment Setup)
- In a new Anaconda/Command Prompt, cd into TensorFlow/models/research/ directory and run the following command:

```
# From within TensorFlow/models/research/
protoc object_detection/protos/*.proto --python_out=.
```

Important: If you are on Windows and using Protobuf 3.5 or later, the multi-file selection wildcard (i.e *-proto) will not work but you can do one of the following:

Windows Powershell

```
# From within TensorFlow/models/research/
Get-ChildItem object_detection/protos/*.proto | foreach {protoc "object_detection/protos/$($_.Name)" --python_out=.}
```

Command Prompt

```
# From within TensorFlow/models/research/
for /f %i in ('dir /b object_detection\protos\*.proto') do protoc object_detection\protos\%i --python_out=.
```

1.4.4 Adding necessary Environment Variables

1. As TensorFlow\models\research\object_detection is the core package for object detection, it's convenient to add the specific folder to our environmental variables.

Linux

This can be done by either adding to ~/.bashrc or running the following:

2 NOTE: You MUST open a new Anaconda/Command Prompt for the changes in the environment variables to take effect.
export PYTHONPATH=$PYTHONPATH:<PATH_TO_TF>/TensorFlow/models/research/object_detection

Windows

The following folder must be added to your PYTHONPATH environment variable (See Environment Setup):

- <PATH_TO_TF>\TensorFlow\models\research\object_detection

Note: The above can also be achieved, in both Linux and Windows environments, by running the following from TensorFlow\models\research:

```bash
# From within TensorFlow/models/research/
python setup.py build
python setup.py install
```

The above commands essentially build and install the object_detection Python package.

**DRAWBACK:** The above commands need to be run everytime there is a change/update of the object_detection package.

2. For whatever reason, some of the TensorFlow packages that are required to perform object detection, do not come pre-installed with our tensorflow installation.

Linux

The Installation docs suggest that you either run, or add to ~/.bashrc file, the following command, which adds these packages to your PYTHONPATH:

```bash
# From within tensorflow/models/research/
export PYTHONPATH=$PYTHONPATH:<PATH_TO_TF>/TensorFlow/models/research:<PATH_TO_TF>/
  →TensorFlow/models/research/slim
```

Windows

The only way that I found works best, is to simply add the following folders to your PYTHONPATH environment variable (See also Environment Setup):

- <PATH_TO_TF>\TensorFlow\models\research
- <PATH_TO_TF>\TensorFlow\models\research\slim

where, in both cases, <PATH_TO_TF> replaces the absolute path to your TensorFlow folder. (e.g. <PATH_TO_TF> = C:\Users\sgvladi\Documents if TensorFlow resides within your Documents folder)

### 1.4.5 COCO API installation (Optional)

The pycocotools package should be installed if you are interested in using COCO evaluation metrics.

Windows

Run the following command to install pycocotools with Windows support:

```bash
pip install git+https://github.com/philferriere/cocoapi.git#subdirectory=PythonAPI
```

Note that, according to the package’s instructions, Visual C++ 2015 build tools must be installed and on your path. If they are not, make sure to install them from here.

Linux
Download cocoapi to a directory of your choice, then make and copy the pycocotools subfolder to the TensorFlow/models/research directory, as such:

```bash
git clone https://github.com/cocodataset/cocoapi.git
cd cocoapi/PythonAPI
make
cp -r pycocotools <PATH_TO_TF>/TensorFlow/models/research/
```

The default metrics are based on those used in Pascal VOC evaluation. To use the COCO object detection metrics add `metrics_set: "coco_detection_metrics"` to the `eval_config` message in the config file. To use the COCO instance segmentation metrics add `metrics_set: "coco_mask_metrics"` to the `eval_config` message in the config file.

### 1.4.6 Test your Installation

- Open a new Anaconda/Command Prompt window and activate the `tensorflow_gpu` environment (if you have not done so already)
- `cd` into `TensorFlow/models/research/object_detection` and run the following command:

  ```bash
  # From within TensorFlow/models/research/object_detection
  jupyter notebook
  ```

  - This should start a new jupyter notebook server on your machine and you should be redirected to a new tab of your default browser.
  - Once there, simply follow sentdex’s Youtube video to ensure that everything is running smoothly.
  - If, when you try to run `In [11]:`, Python crashes, have a look at the Anaconda/Command Prompt window you used to run the jupyter notebook service and check for a line similar (maybe identical) to the one below:

    ```
    2018-03-22 03:07:54.623130: E C:\tf_jenkins\workspace\rel-win\M\windows-gpu\PY\36\tensorflow\stream_executor\cuda\cuda_dnn.cc:378\] Loaded runtime CuDNN library: 7101 (compatibility version 7100) but source was compiled with 7003 (compatibility version 7000). If using a binary, install, upgrade your CuDNN library to match. If building from sources, make sure the library loaded at runtime matches a compatible version specified during compile configuration.
    ```

  - If the above line is present in the printed debugging, it means that you have not installed the correct version of the cuDNN libraries. In this case make sure you re-do the Install CUDNN step, making sure you instal cuDNN v7.0.5.

### 1.5 LabellImg Installation

For Windows and Linux you can download the precompiled binary [here](#). The steps for installing from source follow below.

#### 1.5.1 Create a new Conda virtual environment

To deal with the fact that labelImg (on Windows) requires the use of PyQt4, while tensorflow 1.6 (and possibly other packages) require PyQt5, we will create a new virtual environment in which to run labelImg.

- Open a new Anaconda/Command Prompt window
• Type the following command:

Windows

```bash
conda create -n labelImg pyqt=4
```

Linux

```bash
conda create -n labelImg pyqt=5
```

• The above will create a new virtual environment with name `labelImg`

• Now lets activate the newly created virtual environment by running the following in the Anaconda Promt window:

```bash
activate labelImg
```

Once you have activated your virtual environment, the name of the environment should be displayed within brackets at the beginning of your cmd path specifier, e.g.:

```
(labelImg) C:\Users\sgvladi>
```

1.5.2 Downloading labelImg

• Inside you TensorFlow folder, create a new directory, name it `addons` and then cd into it.

• To download the package you can either use Git to clone the `labelImg` repo inside the `TensorFlow\addons` folder, or you can simply download it as a ZIP and extract it’s contents inside the `TensorFlow\addons` folder. To keep things consistent, in the latter case you will have to rename the extracted folder `labelImg-master` to `labelImg`.

• You should now have a single folder named `addons\labelImg` under your `TensorFlow` folder, which contains another 4 folders as such:

```
TensorFlow
|-- addons
|   |-- labelImg
|   |   |-- models
|       |   |-- official
|       |   |-- research
|       |   |-- samples
|   |-- tutorials
```

1.5.3 Installing dependencies and compiling package

• Open a new Anaconda/Command Prompt window and activate the `tensorflow_gpu` environment (if you have not done so already)

• cd into `TensorFlow\addons\labelImg` and run the following commands:

Windows

```bash
conda install pyqt=4
conda install lxml
pyrcc4 -py3 -o resources.py resources.qrc
```

3 The latest repo commit when writing this tutorial is 8d1b68.
Linux

```
sudo apt-get install pyqt5-dev-tools
sudo pip install -r requirements/requirements-linux-python3.txt
make qt5py3
```

### 1.5.4 Test your installation

- Open a new *Anaconda/Command Prompt* window and activate the `tensorflow_gpu` environment (if you have not done so already)
- `cd` into `TensorFlow\addons\labelImg` and run the following command:

```
python labelImg.py
# or
python labelImg.py [IMAGE_PATH] [PRE-DEFINED CLASS FILE]
```
Hereby you can find an example which allows you to use your camera to generate a video stream, based on which you can perform object_detection.

```python
import numpy as np
import os
import six.moves.urllib as urllib
import sys
import tarfile
import tensorflow as tf
import zipfile
import cv2
from collections import defaultdict
from io import StringIO
from matplotlib import pyplot as plt
from PIL import Image
from utils import label_map_util
from utils import visualization_utils as vis_util

# Define the video stream
cap = cv2.VideoCapture(0)  # Change only if you have more than one webcams

# What model to download.
# Models can bee found here: https://github.com/tensorflow/models/blob/master/research/object_detection/g3doc/detection_model_zoo.md
MODEL_NAME = 'ssd_inception_v2_coco_2017_11_17'
MODEL_FILE = MODEL_NAME + '.tar.gz'
DOWNLOAD_BASE = 'http://download.tensorflow.org/models/object_detection/

# Path to frozen detection graph. This is the actual model that is used for the
# object detection.
PATH_TO_CKPT = MODEL_NAME + '/frozen_inference_graph.pb'

# List of the strings that is used to add correct label for each box.
```

(continues on next page)
PATH_TO_LABELS = os.path.join('data', 'mscoco_label_map.pbtxt')

# Number of classes to detect
NUM_CLASSES = 90

# Download Model
opener = urllib.request.URLopener()
opener.retrieve(DOWNLOAD_BASE + MODEL_FILE, MODEL_FILE)
tar_file = tarfile.open(MODEL_FILE)
for file in tar_file.getmembers():
    file_name = os.path.basename(file.name)
    if 'frozen_inference_graph.pb' in file_name:
        tar_file.extract(file, os.getcwd())

# Load a (frozen) Tensorflow model into memory.
detection_graph = tf.Graph()
with detection_graph.as_default():
    od_graph_def = tf.GraphDef()
    with tf.gfile.GFile(PATH_TO_CKPT, 'rb') as fid:
        serialized_graph = fid.read()
        od_graph_def.ParseFromString(serialized_graph)
        tf.import_graph_def(od_graph_def, name='')

# Loading label map
# Label maps map indices to category names, so that when our convolution network
# predicts '5', we know that this corresponds to 'airplane'. Here we use internal
# utility functions, but anything that returns a dictionary mapping integers to
# appropriate string labels would be fine
label_map = label_map_util.load_labelmap(PATH_TO_LABELS)
categories = label_map_util.convert_label_map_to_categories(
    label_map, max_num_classes=NUM_CLASSES, use_display_name=True)
category_index = label_map_util.create_category_index(categories)

# Helper code
def load_image_into_numpy_array(image):
    (im_width, im_height) = image.size
    return np.array(image.getdata()).reshape((im_height, im_width, 3)).astype(np.uint8)

# Detection
with detection_graph.as_default():
    with tf.Session(graph=detection_graph) as sess:
        while True:

            # Read frame from camera
            ret, image_np = cap.read()
            # Expand dimensions since the model expects images to have shape: [1,]
            image_np_expanded = np.expand_dims(image_np, axis=0)
            # Extract image tensor
            image_tensor = detection_graph.get_tensor_by_name('image_tensor:0')
            # Extract detection boxes
            boxes = detection_graph.get_tensor_by_name('detection_boxes:0')
# Extract detection scores
scores = detection_graph.get_tensor_by_name('detection_scores:0')

# Extract detection classes
classes = detection_graph.get_tensor_by_name('detection_classes:0')

# Extract number of detections
num_detections = detection_graph.get_tensor_by_name('num_detections:0')

# Actual detection.
(boxes, scores, classes, num_detections) = sess.run(
    [boxes, scores, classes, num_detections],
    feed_dict={image_tensor: image_np_expanded})

# Visualization of the results of a detection.
vis_util.visualize_boxes_and_labels_on_image_array(
    image_np,
    np.squeeze(boxes),
    np.squeeze(classes).astype(np.int32),
    np.squeeze(scores),
    category_index,
    use_normalized_coordinates=True,
    line_thickness=8)

# Display output
cv2.imshow('object detection', cv2.resize(image_np, (800, 600)))

if cv2.waitKey(25) & 0xFF == ord('q'):
    cv2.destroyAllWindows()
    break
Training Custom Object Detector

So, up to now you should have done the following:

- Installed TensorFlow, either CPU or GPU (See TensorFlow Installation)
- Installed TensorFlow Models (See TensorFlow Models Installation)
- Installed labelImg (See LabelImg Installation)

Now that we have done all the above, we can start doing some cool stuff. Here we will see how you can train your own object detector, and since it is not as simple as it sounds, we will have a look at:

1. How to organise your workspace/training files
2. How to prepare/annotate image datasets
3. How to generate tf records from such datasets
4. How to configure a simple training pipeline
5. How to train a model and monitor it’s progress
6. How to export the resulting model and use it to detect objects.

3.1 Preparing workspace

1. If you have followed the tutorial, you should by now have a folder Tensorflow, placed under <PATH_TO_TF> (e.g. C:\Users\sgvladi\Documents), with the following directory tree:

```plaintext
TensorFlow
  addons
    labelImg
  models
    official
    research
    samples
    tutorials
```
2. Now create a new folder under TensorFlow and call it workspace. It is within the workspace that we will store all our training set-ups. Now let’s go under workspace and create another folder named training_demo. Now our directory structure should be as so:

```
TensorFlow
  - addons
    - labelImg
  - models
    - official
    - research
    - samples
    - tutorials
  workspace
    - training_demo
```

3. The training_demo folder shall be our training folder, which will contain all files related to our model training. It is advisable to create a separate training folder each time we wish to train a different model. The typical structure for training folders is shown below.

```
training_demo
  - annotations
  - images
    - test
    - train
  - pre-trained-model
  - training
  README.md
```

Here’s an explanation for each of the folders/filer shown in the above tree:

- **annotations**: This folder will be used to store all *.csv files and the respective TensorFlow *.record files, which contain the list of annotations for our dataset images.

- **images**: This folder contains a copy of all the images in our dataset, as well as the respective *.xml files produced for each one, once labelImg is used to annotate objects.
  - images\train: This folder contains a copy of all images, and the respective *.xml files, which will be used to train our model.
  - images\test: This folder contains a copy of all images, and the respective *.xml files, which will be used to test our model.

- **pre-trained-model**: This folder will contain the pre-trained model of our choice, which shall be used as a starting checkpoint for our training job.

- **training**: This folder will contain the training pipeline configuration file *.config, as well as a *.pbtxt label map file and all files generated during the training of our model.

- **README.md**: This is an optional file which provides some general information regarding the training conditions of our model. It is not used by TensorFlow in any way, but it generally helps when you have a few training folders and/or you are revisiting a trained model after some time.

If you do not understand most of the things mentioned above, no need to worry, as we’ll see how all the files are generated further down.
3.2 Annotating images

To annotate images we will be using the labelImg package. If you haven’t installed the package yet, then have a look at LabelImg Installation.

- Once you have collected all the images to be used to test your model (ideally more than 100 per class), place them inside the folder training_demo\images.
- Open a new Anaconda/Command Prompt window and cd into Tensorflow\addons\labelImg.
- If (as suggested in LabelImg Installation) you created a separate Conda environment for labelImg then go ahead and activate it by running:

  ```bash
  activate labelImg
  ```

- Next go ahead and start labelImg, pointing it to your training_demo\images folder.

  ```bash
  python labelImg.py ..\..\workspace\training_demo\images
  ```

- A File Explorer Dialog windows should open, which points to the training_demo\images folder.
- Press the “Select Folder” button, to start annotating your images.

Once open, you should see a window similar to the one below:

I won’t be covering a tutorial on how to use labelImg, but you can have a look at labelImg’s repo for more details. A nice Youtube video demonstrating how to use labelImg is also available here. What is important is that once you annotate all your images, a set of new *.xml files, one for each image, should be generated inside your training_demo\images folder.

Once you have finished annotating your image dataset, it is a general convention to use only part of it for training, and the rest is used for testing purposes. Typically, the ratio is 90%/10%, i.e. 90% of the images are used for training and the rest 10% is maintained for testing, but you can chose whatever ratio suits your needs.

Once you have decided how you will be splitting your dataset, copy all training images, together with their corresponding *.xml files, and place them inside the training_demo\images\train folder. Similarly, copy all
testing images, with their *.xml files, and paste them inside training_demo\images\train.

### 3.3 Creating Label Map

TensorFlow requires a label map, which namely maps each of the used labels to an integer values. This label map is used both by the training and detection processes.

Below I show an example label map (e.g label_map.pbtxt), assuming that our dataset contains 2 labels, dogs and cats:

```python
item {
  id: 1
  name: 'cat'
}

item {
  id: 2
  name: 'dog'
}
```

Label map files have the extension .pbtxt and should be placed inside the training_demo\annotations folder.

### 3.4 Creating TensorFlow Records

Now that we have generated our annotations and split our dataset into the desired training and testing subsets, it is time to convert our annotations into the so called TFRecord format.

There are two steps in doing so:

- Converting the individual *.xml files to a unified *.csv file for each dataset.
- Converting the *.csv files of each dataset to *.record files (TFRecord format).

Before we proceed to describe the above steps, let’s create a directory where we can store some scripts. Under the TensorFlow folder, create a new folder TensorFlow\scripts, which we can use to store some useful scripts. To make things even tidier, let’s create a new folder TensorFlow\scripts\preprocessing, where we shall store scripts that we can use to preprocess our training inputs. Below is our TensorFlow directory tree structure, up to now:

```
TensorFlow
  ├── addons
  │    └── labelImg
  ├── models
  │    ├── official
  │    │    └── research
  │    ├── research
  │    │    └── samples
  │    │    └── samples
  │    │    └── tutorials
  ├── scripts
  │    └── preprocessing
  ├── workspace
  │    └── training_demo
```
3.4.1 Converting *.xml to *.csv

To do this we can write a simple script that iterates through all *.xml files in the training_demo\images\train and training_demo\images\test folders, and generates a *.csv for each of the two.

Here is an example script that allows us to do just that:

```python
# Create train data:
python xml_to_csv.py -i [PATH_TO_IMAGES_FOLDER]/train -o [PATH_TO_ANNOTATIONS_FOLDER]/train_labels.csv

# Create test data:
python xml_to_csv.py -i [PATH_TO_IMAGES_FOLDER]/test -o [PATH_TO_ANNOTATIONS_FOLDER]/test_labels.csv
```

```python
import os
import glob
import pandas as pd
import argparse
import xml.etree.ElementTree as ET

def xml_to_csv(path):
    """Iterates through all .xml files (generated by labelImg) in a given directory and combines them in a single Pandas datagrame."
    xml_list = []
    for xml_file in glob.glob(path + '/*.xml'):
        tree = ET.parse(xml_file)
        root = tree.getroot()
        for member in root.findall('object'):
            value = (root.find('filename').text,
                     int(root.find('size')[0].text),
                     int(root.find('size')[1].text),
                     member[0].text,
                     int(member[4][0].text),
                     int(member[4][1].text),
                     int(member[4][2].text),
                     int(member[4][3].text)
                     )
            xml_list.append(value)
    column_name = ['filename', 'width', 'height',
                   'class', 'xmin', 'ymin', 'xmax', 'ymax']
    xml_df = pd.DataFrame(xml_list, columns=column_name)
```

(continues on next page)
return xml_df

def main():
    # Initiate argument parser
    parser = argparse.ArgumentParser(
        description="Sample TensorFlow XML-to-CSV converter")
    parser.add_argument("-i",
        "--inputDir",
        help="Path to the folder where the input .xml files are stored",
        type=str)
    parser.add_argument("-o",
        "--outputFile",
        help="Name of output .csv file (including path)", type=str)
    args = parser.parse_args()

    if(args.inputDir is None):
        args.inputDir = os.getcwd()
    if(args.outputFile is None):
        args.outputFile = args.inputDir + "/labels.csv"

    assert(os.path.isdir(args.inputDir))

    xml_df = xml_to_csv(args.inputDir)
    xml_df.to_csv(args.outputFile, index=None)
    print('Successfully converted xml to csv.

if __name__ == '__main__':
    main()

• Create a new file with name xml_to_csv.py under TensorFlow\scripts\preprocessing, open it, paste the above code inside it and save.

• Install the pandas package:
  conda install pandas  # Anaconda
  # or
  pip install pandas  # pip

• Finally, cd into TensorFlow\scripts\preprocessing and run:

  # Create train data:
  python xml_to_csv.py -i [PATH_TO_IMAGES_FOLDER]/train -o [PATH_TO_  
  └Annotations_FOLDER]/train_labels.csv

  # Create test data:
  python xml_to_csv.py -i [PATH_TO_IMAGES_FOLDER]/test -o [PATH_TO_  
  └Annotations_FOLDER]/test_labels.csv

  # For example
  # python xml_to_csv.py -i  
  "C:\Users\sqlvladi\Documents\TensorFlow\workspace\training_  
  └demo\images\train -o
  "C:\Users\sqlvladi\Documents\TensorFlow\workspace\training_  
  └demo\annotations\train_labels.csv

(continues on next page)
Once the above is done, there should be 2 new files under the training_demo\annotations folder, named test_labels.csv and train_labels.csv, respectively.

### 3.4.2 Converting from *.csv to *.record

Now that we have obtained our *.csv annotation files, we will need to convert them into TFRecords. Below is an example script that allows us to do just that:

```python
# Import necessary libraries
import os
import io
import pandas as pd
import tensorflow as tf
import sys

# Append path to models/research directory
sys.path.append("../models/research")

# Import necessary functions
from PIL import Image
from object_detection.utils import dataset_util
from collections import namedtuple, OrderedDict

flags = tf.app.flags
flags.DEFINE_string('csv_input', '', 'Path to the CSV input')
flags.DEFINE_string('output_path', '', 'Path to output TFRecord')
flags.DEFINE_string('label', '', 'Name of class label')
flags.DEFINE_string('img_path', '', 'Path to images')

FLAGS = flags.FLAGS

# TO-DO replace this with label map
# for multiple labels add more else if statements

# Define a function to convert the csv file into a tensorflow record
def create_tf_exampleぺlr
    # Use the pandas library to read the csv file
    df = pd.read_csv(FLAGS.csv_input)

    # Create a dictionary to store the information
    image_data = df.to_dict()

    # Define the function to create the tf_example
    def _create_tf_example(image_data):
        # Create a dictionary to store the data
        image_dict = {
            'filename': image_data['filename'][0],
            'height': int(image_data['height'][0]),
            'width': int(image_data['width'][0]),
            'depth': 3,
            'x_min': float(image_data['x_min'][0]),
            'x_max': float(image_data['x_max'][0]),
            'y_min': float(image_data['y_min'][0]),
            'y_max': float(image_data['y_max'][0]),
            'label': FLAGS.label
        }

        # Create a tf_example
        tf_example = tf.train.Example(
            features=tf.train.Features(
                feature={
                    'image/height': tf.train.Feature(int64_list=tf.train.Int64List(value=[image_dict['height']])),
                    'image/width': tf.train.Feature(int64_list=tf.train.Int64List(value=[image_dict['width']])),
                    'image/depth': tf.train.Feature(int64_list=tf.train.Int64List(value=[image_dict['depth']])),
                    'image/x_min': tf.train.Feature(float_list=tf.train.FloatList(value=[image_dict['x_min']])),
                    'image/x_max': tf.train.Feature(float_list=tf.train.FloatList(value=[image_dict['x_max']])),
                    'image/y_min': tf.train.Feature(float_list=tf.train.FloatList(value=[image_dict['y_min']])),
                    'image/y_max': tf.train.Feature(float_list=tf.train.FloatList(value=[image_dict['y_max']])),
                    'image/label': tf.train.Feature(int64_list=tf.train.Int64List(value=[image_dict['label']]))
                }
            )
        )

        # Return the tf_example
        return tf_example

    # Create the tf_example
    tf_example = _create_tf_example(image_data)

    return tf_example

# Create the tf_record
with tf.io.TFRecordWriter(FLAGS.output_path) as tf_record:
    # Loop through the images and create a tf_example for each
    for image in image_data:
        tf_example = create_tf_example(image)
        tf_record.write(tf_example.SerializeToString())
```

3.4. Creating TensorFlow Records
```python
def class_text_to_int(row_label):
    if row_label == FLAGS.label:  # 'ship':
        return 1
    # comment upper if statement and uncomment these statements for multiple labelling
    # if row_label == FLAGS.label0:
    #    return 1
    # elif row_label == FLAGS.label1:
    #    return 0
    else:
        None

def split(df, group):
    data = namedtuple('data', ['filename', 'object'])
    gb = df.groupby(group)
    return [data(filename, gb.get_group(x)) for filename, x in zip(gb.groups.keys(), gb.groups)]

def create_tf_example(group, path):
    with tf.gfile.GFile(os.path.join(path, '{}'.format(group.filename)), 'rb') as fid:
        encoded_jpg = fid.read()
        encoded_jpg_io = io.BytesIO(encoded_jpg)
        image = Image.open(encoded_jpg_io)
        width, height = image.size
        filename = group.filename.encode('utf8')
        image_format = b'jpg'
        # check if the image format is matching with your images.
        xmins = []
        xmaxs = []
        ymins = []
        ymaxs = []
        classes_text = []
        classes = []
        for index, row in group.object.iterrows():
            xmins.append(row['xmin'] / width)
            xmaxs.append(row['xmax'] / width)
            ymins.append(row['ymin'] / height)
            ymaxs.append(row['ymax'] / height)
            classes_text.append(row['class'].encode('utf8'))
            classes.append(class_text_to_int(row['class']))
        tf_example = tf.train.Example(features=tf.train.Features(feature={
            'image/height': dataset_util.int64_feature(height),
            'image/width': dataset_util.int64_feature(width),
            'image/filename': dataset_util.bytes_feature(filename),
            'image/source_id': dataset_util.bytes_feature(filename),
            'image/encoded': dataset_util.bytes_feature(encoded_jpg),
            'image/format': dataset_util.bytes_feature(image_format),
            'image/object/bbox/xmin': dataset_util.float_list_feature(xmins),
            'image/object/bbox/xmax': dataset_util.float_list_feature(xmaxs),
            'image/object/bbox/ymin': dataset_util.float_list_feature(ymins),
            'image/object/bbox/ymax': dataset_util.float_list_feature(ymaxs),
            'image/object/class/text': dataset_util.bytes_list_feature(classes_text),
            'image/object/class/label': dataset_util.int64_list_feature(classes),
        })
```

(continues on next page)
def main(_):
    writer = tf.python_io.TFRecordWriter(FLAGS.output_path)
    path = os.path.join(os.getcwd(), FLAGS.img_path)
    examples = pd.read_csv(FLAGS.csv_input)
    grouped = split(examples, 'filename')
    for group in grouped:
        tf_example = create_tf_example(group, path)
        writer.write(tf_example.SerializeToString())
    writer.close()
    output_path = os.path.join(os.getcwd(), FLAGS.output_path)
    print('Successfully created the TFRecords: {}'.format(output_path))

if __name__ == '__main__':
    tf.app.run()

• Create a new file with name generate_tfrecord.py under TensorFlow\scripts\preprocessing, open it, paste the above code inside it and save.

• Once this is done, cd into TensorFlow\scripts\preprocessing and run:

```
# Create train data:
python generate_tfrecord.py --label=<LABEL> --csv_input=<PATH_TO_ANNOTATIONS_FOLDER>/train_labels.csv --img_path=<PATH_TO_IMAGES_FOLDER>/train --output_path=<PATH_TO_ANNOTATIONS_FOLDER>/train.record

# Create test data:
python generate_tfrecord.py --label=<LABEL> --csv_input=<PATH_TO_ANNOTATIONS_FOLDER>/test_labels.csv --img_path=<PATH_TO_IMAGES_FOLDER>/test --output_path=<PATH_TO_ANNOTATIONS_FOLDER>/test.record

# For example
# python generate_tfrecord.py --label=ship --csv_input=C:\Users\sglvladi\Documents\TensorFlow\workspace\training\demo\annotations\train_labels.csv --output=C:\Users\sglvladi\Documents\TensorFlow\workspace\training\demo\images\train
# python generate_tfrecord.py --label=ship --csv_input=C:\Users\sglvladi\Documents\TensorFlow\workspace\training\demo\annotations\test_labels.csv --output=C:\Users\sglvladi\Documents\TensorFlow\workspace\training\demo\images\test
```

Once the above is done, there should be 2 new files under the training_demo\annotations folder, named test.record and train.record, respectively.

3.4. Creating TensorFlow Records
3.5 Configuring a Training Pipeline

For the purposes of this tutorial we will not be creating a training job from the scratch, but rather we will go through how to reuse one of the pre-trained models provided by TensorFlow. If you would like to train an entirely new model, you can have a look at TensorFlow’s tutorial.

The model we shall be using in our examples is the `ssd_inception_v2_coco` model, since it provides a relatively good trade-off between performance and speed, however there are a number of other models you can use, all of which are listed in TensorFlow’s detection model zoo. More information about the detection performance, as well as reference times of execution, for each of the available pre-trained models can be found here.

First of all, we need to get ourselves the sample pipeline configuration file for the specific model we wish to retrain. You can find the specific file for the model of your choice here. In our case, since we shall be using the `ssd_inception_v2_coco` model, we shall be downloading the corresponding `ssd_inception_v2_coco.config` file.

Apart from the configuration file, we also need to download the latest pre-trained NN for the model we wish to use. This can be done by simply clicking on the name of the desired model in the tables found in TensorFlow’s detection model zoo. Clicking on the name of your model should initiate a download for a `*.tar.gz` file.

Once the `*.tar.gz` file has been downloaded, open it using a decompression program of your choice (e.g. 7zip, WinZIP, etc.). Next, open the folder that you see when the compressed folder is opened (typically it will have the same name as the compressed folded, without the `*.tar.gz` extension), and extract it’s contents inside the folder `training_demo\pre-trained-model`.

Now that we have downloaded and extracted our pre-trained model, let’s have a look at the changes that we shall need to apply to the downloaded `*.config` file (highlighted in yellow):

```
# SSD with Inception v2 configuration for MSCOCO Dataset.
# Users should configure the fine_tune_checkpoint field in the train config as
# well as the label_map_path and input_path fields in the train_input_reader and
# eval_input_reader. Search for "PATH_TO_BE_CONFIGURED" to find the fields that
# should be configured.

model {
  ssd {
    num_classes: 1 # Set this to the number of different label classes
    box_coder {
      faster_rcnn_box_coder {
        y_scale: 10.0
        x_scale: 10.0
        height_scale: 5.0
        width_scale: 5.0
      }
    }
    matcher {
      argmax_matcher {
        matched_threshold: 0.5
        unmatched_threshold: 0.5
        ignore_thresholds: false
        negatives_lower_than_unmatched: true
        force_match_for_each_row: true
      }
    }
    similarity_calculator {
      iou_similarity {
      }
    }
  }
  anchor_generator {
```

(continues on next page)
ssd_anchor_generator {
  num_layers: 6
  min_scale: 0.2
  max_scale: 0.95
  aspect_ratios: 1.0
  aspect_ratios: 2.0
  aspect_ratios: 0.5
  aspect_ratios: 3.0
  aspect_ratios: 0.3333
  reduce_boxes_in_lowest_layer: true
}

image_resizer {
  fixed_shape_resizer {
    height: 300
    width: 300
  }
}

box_predictor {
  convolutional_box_predictor {
    min_depth: 0
    max_depth: 0
    num_layers_before_predictor: 0
    use_dropout: false
    dropout_keep_probability: 0.8
    kernel_size: 3
    box_code_size: 4
    apply_sigmoid_to_scores: false
    conv_hyperparams {
      activation: RELU_6,
      regularizer {
        l2_regularizer {
          weight: 0.00004
        }
      }
      initializer {
        truncated_normal_initializer {
          stddev: 0.03
          mean: 0.0
        }
      }
    }
    feature_extractor {
      type: 'ssd_inception_v2' # Set to the name of your chosen pre-trained model
      min_depth: 16
      depth_multiplier: 1.0
      conv_hyperparams {
        activation: RELU_6,
        regularizer {
          l2_regularizer {
            weight: 0.00004
          }
        }
        initializer {
          truncated_normal_initializer {
            stddev: 0.03
            mean: 0.0
          }
        }
      }
    }
  }
}

3.5. Configuring a Training Pipeline
truncated_normal_initializer {
  stddev: 0.03
  mean: 0.0
}
}

batch_norm {
  train: true,
  scale: true,
  center: true,
  decay: 0.9997,
  epsilon: 0.0001,
}

override_base_feature_extractor_hyperparams: true

loss {
  classification_loss {
    weighted_sigmoid {
    }
  }
  localization_loss {
    weighted_smooth_l1 {
    }
  }
  hard_example_miner {
    num_hard_examples: 3000
    iou_threshold: 0.99
    loss_type: CLASSIFICATION
    max_negatives_per_positive: 3
    min_negatives_per_image: 0
  }
  classification_weight: 1.0
  localization_weight: 1.0
}
normalize_loss_by_num_matches: true
post_processing {
  batch_non_max_suppression {
    score_threshold: 1e-8
    iou_threshold: 0.6
    max_detections_per_class: 100
    max_total_detections: 100
  }
  score_converter: SIGMOID
}
}

train_config: {
  batch_size: 12 # Increase/Decrease this value depending on the available memory.
  optimizer {
    rms_prop_optimizer: {
      learning_rate: {
        exponential_decay_learning_rate {
          initial_learning_rate: 0.004
          decay_steps: 800720
          decay_factor: 0.95
        }
      }
    }
  }
}
Once the above changes have been applied to our config file, go ahead and save it under training_demo/training.

### 3.6 Training the Model

Before we begin training our model, let’s go and copy the TensorFlow/models/research/object_detection/legacy/train.py script and paste it straight into our training_demo folder.
We will need this script in order to train our model.

Now, to initiate a new training job, cd inside the training_demo folder and type the following:

```
python train.py --logtostderr --train_dir=training/ --pipeline_config_path=training/__ssd_inception_v2_coco.config
```

Once the training process has been initiated, you should see a series of print outs similar to the one below (plus/minus some warnings):

```
INFO:tensorflow:depth of additional conv before box predictor: 0
INFO:tensorflow:depth of additional conv before box predictor: 0
INFO:tensorflow:depth of additional conv before box predictor: 0
INFO:tensorflow:depth of additional conv before box predictor: 0
INFO:tensorflow:depth of additional conv before box predictor: 0
INFO:tensorflow:depth of additional conv before box predictor: 0
INFO:tensorflow:Restoring parameters from ssd_inception_v2_coco_2017_11_17/model.ckpt
INFO:tensorflow:Running local_init_op.
INFO:tensorflow:Done running local_init_op.
INFO:tensorflow:Starting Session.
INFO:tensorflow:Saving checkpoint to path training/model.ckpt
INFO:tensorflow:Starting Queues.
INFO:tensorflow:global_step/sec: 0
INFO:tensorflow:global_step 2: loss = 16.2202 (0.937 sec/step)
INFO:tensorflow:global_step 3: loss = 13.7876 (0.904 sec/step)
INFO:tensorflow:global_step 4: loss = 12.9230 (0.894 sec/step)
INFO:tensorflow:global_step 5: loss = 12.7497 (0.922 sec/step)
INFO:tensorflow:global_step 6: loss = 11.7563 (0.936 sec/step)
INFO:tensorflow:global_step 7: loss = 11.7245 (0.910 sec/step)
INFO:tensorflow:global_step 8: loss = 10.7993 (0.916 sec/step)
INFO:tensorflow:global_step 9: loss = 9.1277 (0.890 sec/step)
INFO:tensorflow:global_step 10: loss = 9.3972 (0.919 sec/step)
INFO:tensorflow:global_step 11: loss = 9.9487 (0.897 sec/step)
INFO:tensorflow:global_step 12: loss = 8.7954 (0.884 sec/step)
INFO:tensorflow:global_step 13: loss = 7.4329 (0.906 sec/step)
INFO:tensorflow:global_step 14: loss = 7.8270 (0.897 sec/step)
INFO:tensorflow:global_step 15: loss = 6.4877 (0.894 sec/step)
```

If you ARE NOT seeing a print-out similar to that shown above, and/or the training job crashes after a few seconds, then have a look at the issues and proposed solutions, under the Common issues section, to see if you can find a solution. Alternatively, you can try the issues section of the official Tensorflow Models repo.

If you ARE observing a similar output to the above, then CONGRATULATIONS, you have successfully started your first training job. Now you may very well treat yourself to a cold beer, as waiting on the training to finish is likely to take a while. Following what people have said online, it seems that it is advisable to allow your model to reach a TotalLoss of at least 2 (ideally 1 and lower) if you want to achieve “fair” detection results. Obviously, lower TotalLoss is better, however very low TotalLoss should be avoided, as the model may end up overfitting the dataset, meaning that it will perform poorly when applied to images outside the dataset. To monitor TotalLoss, as well as a number of other metrics, while your model is training, have a look at Monitor Training Job Progress using TensorBoard.

Training times can be affected by a number of factors such as:

- The computational power of you hardware (either CPU or GPU): Obviously, the more powerful your PC is, the faster the training process.
- Whether you are using the TensorFlow CPU or GPU variant: In general, even when compared to the best
CPUs, almost any GPU graphics card will yield much faster training and detection speeds. As a matter of fact, when I first started I was running TensorFlow on my Intel i7-5930k (6/12 cores @ 4GHz, 32GB RAM) and was getting step times of around 12 sec/step, after which I installed TensorFlow GPU and training the very same model -using the same dataset and config files- on a EVGA GTX-770 (1536 CUDA-cores @ 1GHz, 2GB VRAM) I was down to 0.9 sec/step!!! A 12-fold increase in speed, using a “low/mid-end” graphics card, when compared to a “mid/high-end” CPU.

- How big the dataset is: The higher the number of images in your dataset, the longer it will take for the model to reach satisfactory levels of detection performance.

- The complexity of the objects you are trying to detect: Obviously, if your objective is to track a black ball over a white background, the model will converge to satisfactory levels of detection pretty quickly. If on the other hand, for example, you wish to detect ships in ports, using Pan-Tilt-Zoom cameras, then training will be a much more challenging and time-consuming process, due to the high variability of the shape and size of ships, combined with a highly dynamic background.

- And many, many, many, more….

3.7 Monitor Training Job Progress using TensorBoard

A very nice feature of TensorFlow, is that it allows you to continuously monitor and visualise a number of different training/detection performance metrics, while your model is being trained. The specific tool that allows us to do all that is Tensorboard.

To start a new TensorBoard server, we follow the following steps:

- Open a new Anaconda/Command Prompt
- Activate your TensorFlow conda environment (if you have one), e.g.:
  
  ```
  activate tensorflow_gpu
  ```

- cd into the training_demo folder.
- Run the following command:
  
  ```
  tensorboard --logdir=training/
  ```

The above command will start a new TensorBoard server, which (by default) listens to port 6006 of your machine. Assuming that everything went well, you should see a print-out similar to the one below (plus/minus some warnings):

```
TensorBoard 1.6.0 at http://YOUR-PC:6006 (Press CTRL+C to quit)
```

Once this is done, go to your browser and type http://YOUR-PC:6006 in your address bar, following which you should be presented with a dashboard similar to the one shown below (maybe less populated if your model has just started training):
3.8 Exporting a Trained Inference Graph

Once your training job is complete, you need to extract the newly trained inference graph, which will be later used to perform the object detection. This can be done as follows:

- Open a new Anaconda/Command Prompt
- Activate your TensorFlow conda environment (if you have one), e.g.:

  ```bash
  activate tensorflow_gpu
  ```
- Copy the `TensorFlow/models/research/object_detection/export_inference_graph.py` script and paste it straight into your training_demo folder.
- Check inside your training_demo/training folder for the `model.ckpt-*` checkpoint file with the highest number following the name of the dash e.g. `model.ckpt-34350`). This number represents the training step index at which the file was created.
- Alternatively, simply sort all the files inside training_demo/training by descending time and pick the `model.ckpt-*` file that comes first in the list.
- Make a note of the file’s name, as it will be passed as an argument when we call the `export_inference_graph.py` script.
- Now, cd inside your training_demo folder, and run the following command:

  ```bash
  python export_inference_graph.py --input_type image_tensor --pipeline_config_path --training/ssd_inception_v2_coco.config --trained_checkpoint_prefix training/model.ckpt-13302 --output_directory trained-inference-graphs/output_inference_graph_v1.pb
  ```
CHAPTER 4

Common issues

Below is a list of common issues encountered while using TensorFlow for objects detection.

4.1 Python crashes - TensorFlow GPU

If you are using TensorFlow GPU and when you try to run some Python object detection script (e.g. Test your Installation), after a few seconds, Windows reports that Python has crashed then have a look at the Anaconda/Command Prompt window you used to run the script and check for a line similar (maybe identical) to the one below:

```
2018-03-22 03:07:54.623130: E C:\tf_jenkins\workspace\rel-win\M\windows-\ gpu\PY\36\tensorflow\stream_executor\cuda\cuda_dnn.cc:378] Loaded runtime
CuDNN library: 7101 (compatibility version 7100) but source was compiled
with 7003 (compatibility version 7000). If using a binary install,
upgrade your CuDNN library to match. If building from sources, make sure
the library loaded at runtime matches a compatible version specified
during compile configuration.
```

If the above line is present in the printed debugging, it means that you have not installed the correct version of the cuDNN libraries. In this case make sure you re-do the Install CUDNN step, making sure you instal cuDNN v7.0.5.

4.2 Cleaning up Nvidia containers (TensorFlow GPU)

Sometimes, when terminating a TensorFlow training process, the Nvidia containers associated to the process are not cleanly terminated. This can lead to bogus errors when we try to run a new TensorFlow process.

Some known issues caused by the above are presented below:

- Failure to restart training of a model. Look for the following errors in the debugging:
To solve such issues in Windows, open a Task Manager windows, look for Tasks with name NVIDIA Container and kill them by selecting them and clicking the End Task button at the bottom left corner of the window.

If the issue persists, then you’re probably running out of memory. Try closing down anything else that might be eating up your GPU memory (e.g. Youtube videos, webpages etc.)

### 4.3 labelImg saves annotation files with .xml extension

At the time of writing up this document, I haven’t managed to identify why this might be happening. I have joined a GitHub issue, at which you can refer in case there are any updates.

One way I managed to fix the issue was by clicking on the “Change Save Dir” button and selecting the directory where the annotations files should be stores. By doing so, you should not longer get a pop-up dialog when you click “Save” (or Ctrl+s), but you can always check if the file was saved by looking at the bottom left corner of labelImg.
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