

Manual: Tensorflow Debugging and Visualization Environments

Tensorflow Visualisation

Tensorboard is essentially a visualization toolkit that can be used to track the evolution of various parameters during training a machine learning system.

The variables that are to be tracked are written into a log directory after having generated summary data in the form of a summary writer;

```
file_writer = tf.summary.FileWriter('/path/to/logs', sess.graph)
```

Once the event files (files where the variables are logged into) are ready, use the command

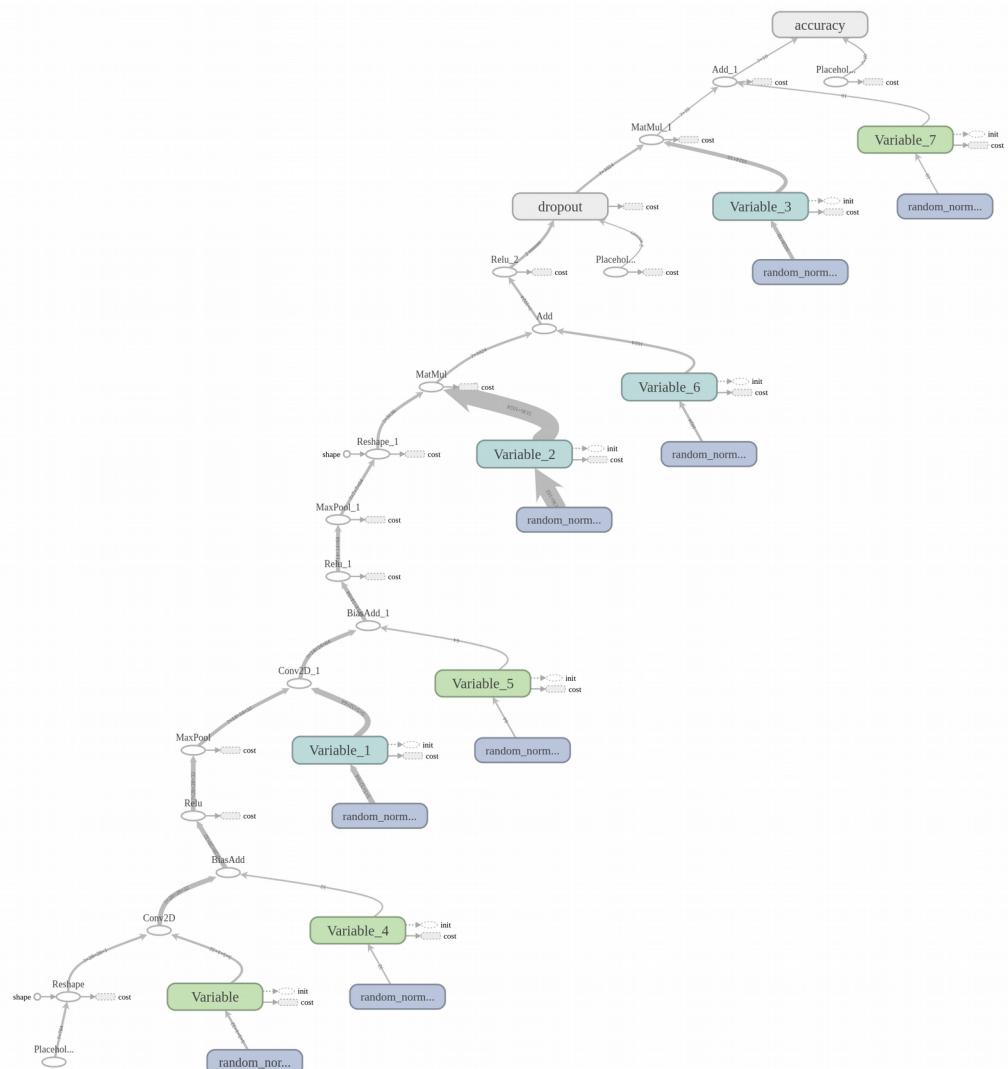
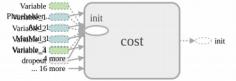
```
$ tensorboard --logdir=pth/to/logs --port 6060
```

(The entire command is important as we'll be using another instance of tensorboard for debugging on port 6006)

Also, keep in mind to launch the above command from the Terminal (Linux and Mac OS) or Command Prompt (Windows). While running either Jupyter notebook or Python script.

Key Concepts:

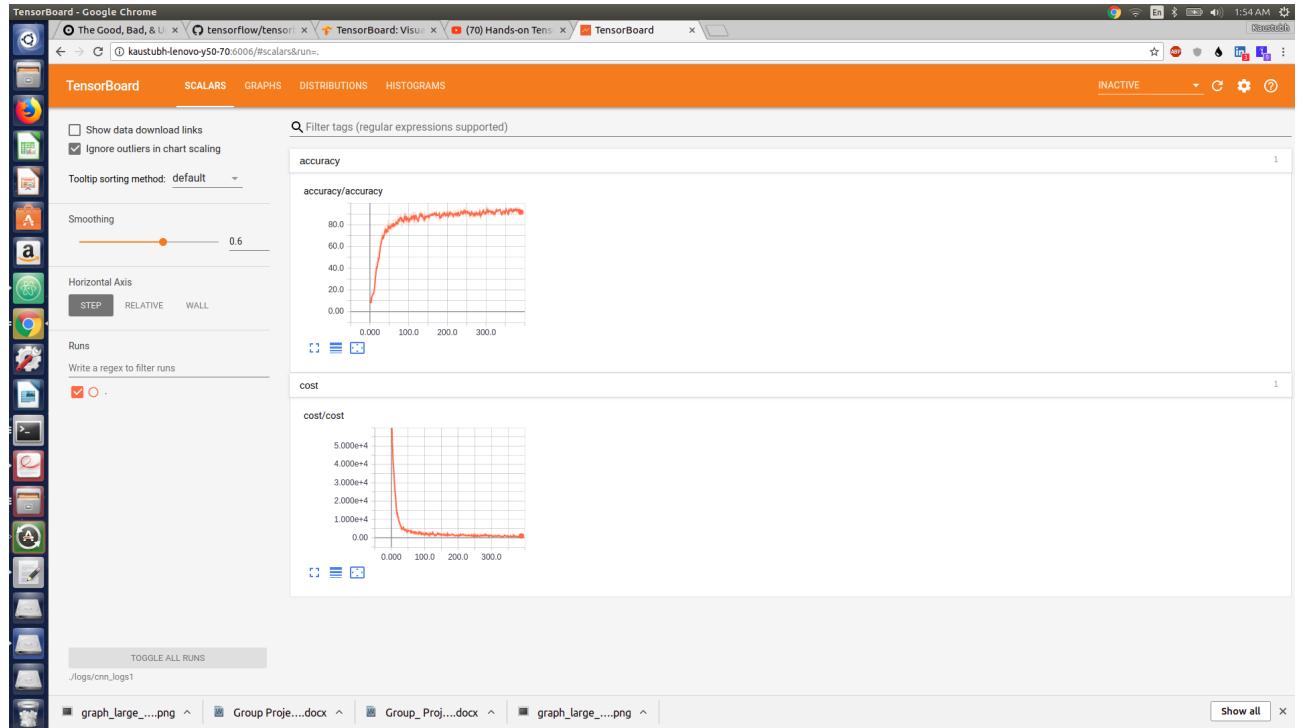
For the *handwritten_digits_recognition_cnn_5layer.ipynb*, the different (graph, scalar, histogram) visualization are illustrated in the following screenshots.



Scalar Dashboard

TensorBoard's Scalar Dashboard visualizes scalar statistics that vary over time; for example, you might want to track the model's loss or learning rate.

Accuracy and loss have been tracked.



The `tf.summary.scalar` object is used to log these changes for visualization.

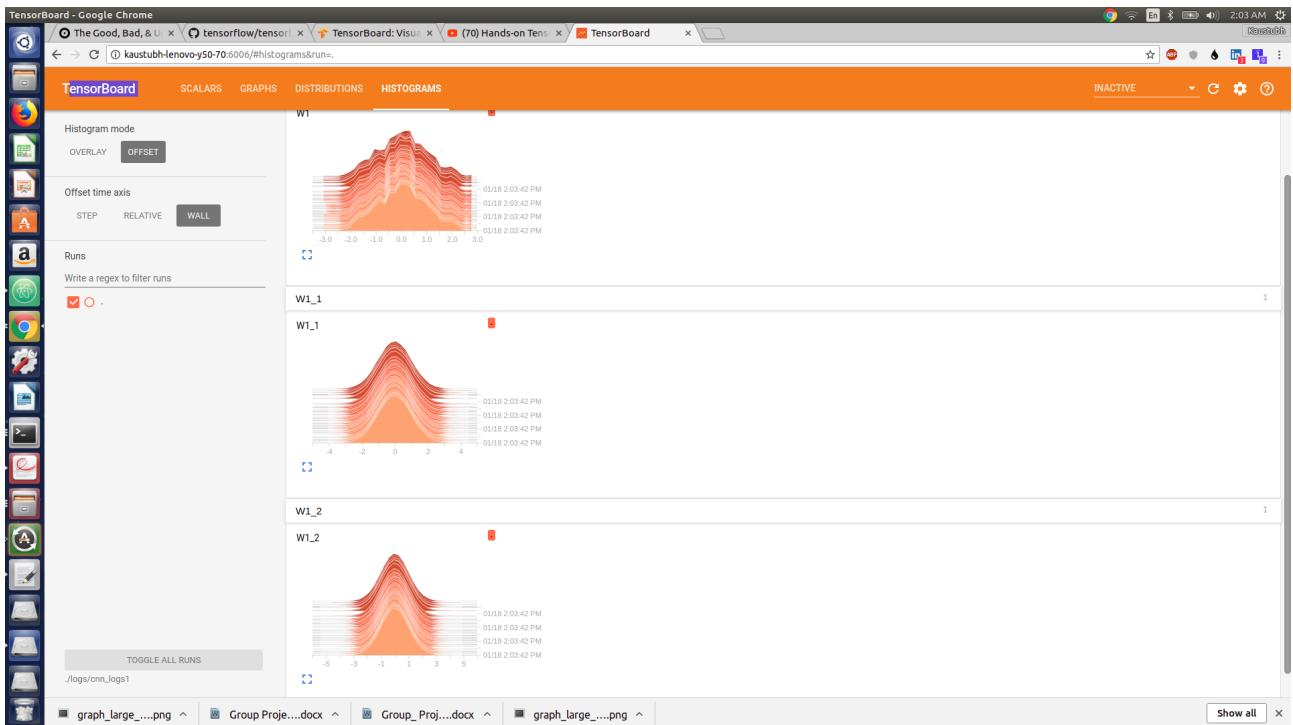
Histogram Dashboard

The HistogramDashboard displays how the statistical distribution of a Tensor has varied over time. It visualizes data recorded through the `tf.summary.histogram` object.

Each chart shows temporal "slices" of data, where each slice is a histogram of the tensor at a given step.

It's organized with the oldest timestep in the back, and the most recent timestep in front.

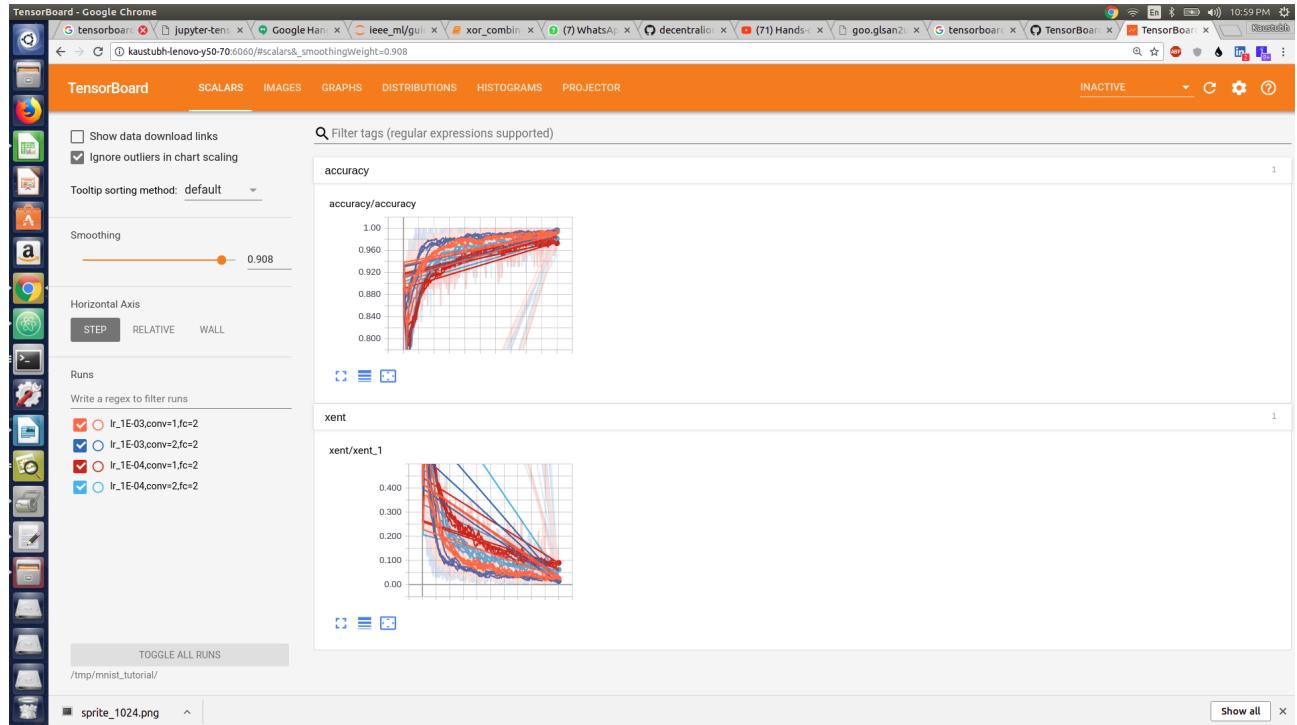
By changing the Histogram Mode from "offset" to "overlay", the perspective will rotate so that every histogram slice is rendered as a line and overlaid with one another.



Hyperparameter Search

Tensorboard also provides option to visualize the performance of a model for different choices of hyperparameters.

This is done on the file `mnist_hyperparameters.py`



The different color codes correspond to different hyperparameter settings which in this case are [learning rate, number of convolution_layers, number of fully_connected_layers].

For a more detailed instructions for using various functionalities of tensorboard; go to

<https://github.com/tensorflow/tensorflow/blob/r1.2/tensorflow/tensorboard/README.md>

Tensorflow Debugger

CLI Debugger

XOR_combined.py

Firstly, the Tensorflow CLI debugger can be used to debug any running computational graph in Tensorflow very succinctly. This is difficult to achieve with standard debuggers like Python's pdb.

It is best recommended to use TF CLI debugger on .py files.

The *tf_debug (TensorflowDebugger)* is a debugger built for tensorflow that enables you to view the internal structure and states of the Tensorflow computational graphs during training and inference.

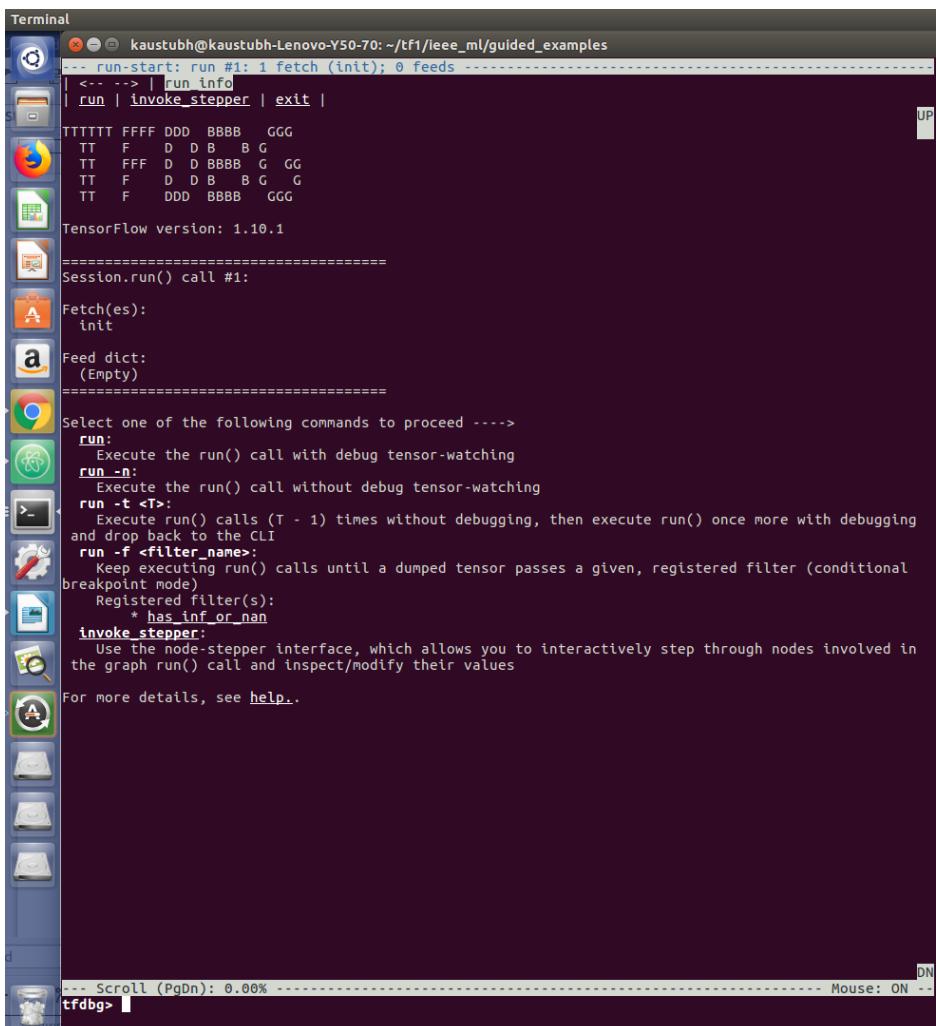
You will have to wrap TF sessions with the tfdbg as:

```
sess = tf_debug.LocalCLIDebugWrapperSession(sess)
```

This wrapper will same interface as Session thus enabling debugging needs no extra code changes.

To launch a TF CLI Debugger on the xor_combined.py;

```
$ python3 xor_combined.py --debug
```



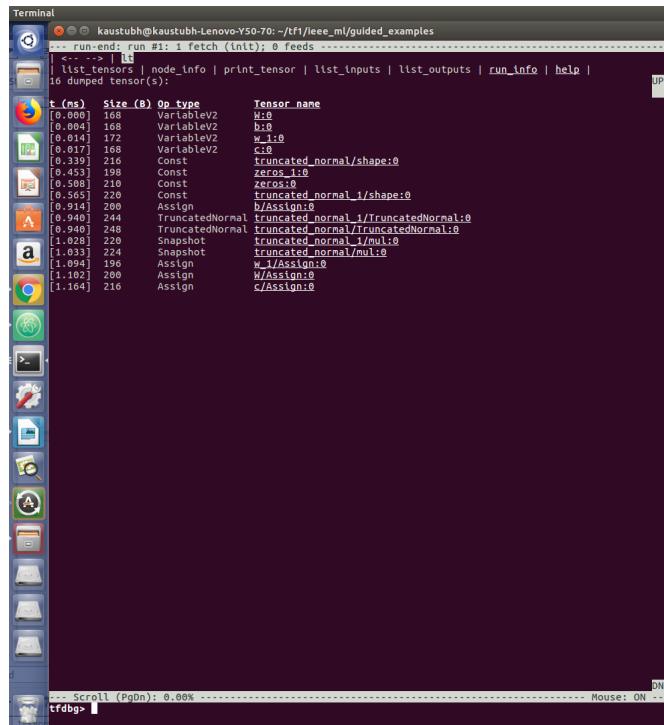
The screenshot shows a terminal window with a dark background and light-colored text. At the top, it says "Terminal" and "kaustubh@kaustubh-Lenovo-Y50-70: ~/tf1/ieee_ml/guided_examples". The main area of the terminal displays the output of the Tensorflow CLI Debugger. It starts with a command prompt: "run-start: run #1: 1 fetch (init); 0 feeds". Below this, there are several lines of binary data: "TTTTT FFFF DDD BBBB GGG", "TT F D D B B G", "TT FFF D D BBBB G GG", "TT F D D B B G G", and "TT F DDD BBBB GGG". Following this, it shows "TensorFlow version: 1.10.1". Then, it prompts for a session run: "Session.run() call #1:". It shows a "Fetch(es)" command with "init" and a "Feed dict: (Empty)". It then asks to select a command: "Select one of the following commands to proceed ---->". The available commands are: "run" (Execute the run() call with debug tensor-watching), "run-n" (Execute the run() call without debug tensor-watching), "run -t <T>" (Execute run() calls (T - 1) times without debugging, then execute run() once more with debugging and drop back to the CLI), "run -f <filter_name>" (Keep executing run() calls until a dumped tensor passes a given, registered filter (conditional breakpoint mode)), "Registered filter(s): * has_inf_or_nan", "invoke stepper" (Use the node-stepper interface, which allows you to interactively step through nodes involved in the graph run() call and inspect/modify their values), and "help" (For more details, see help.). At the bottom of the terminal, it says "tfdbg>" and "--- Scroll (PgDn): 0.00% --- Mouse: ON ---".

The debug wrapper session will prompt you before the first Session.run() call is about to be executed. This is also the run-start CLI. It lists the fetches and the feeds to the current Session.run() call.

Now enter the run command in the terminal;

```
tfdbg> run
```

The run command makes the tf_debug execute until the end of the next Session.run() call.

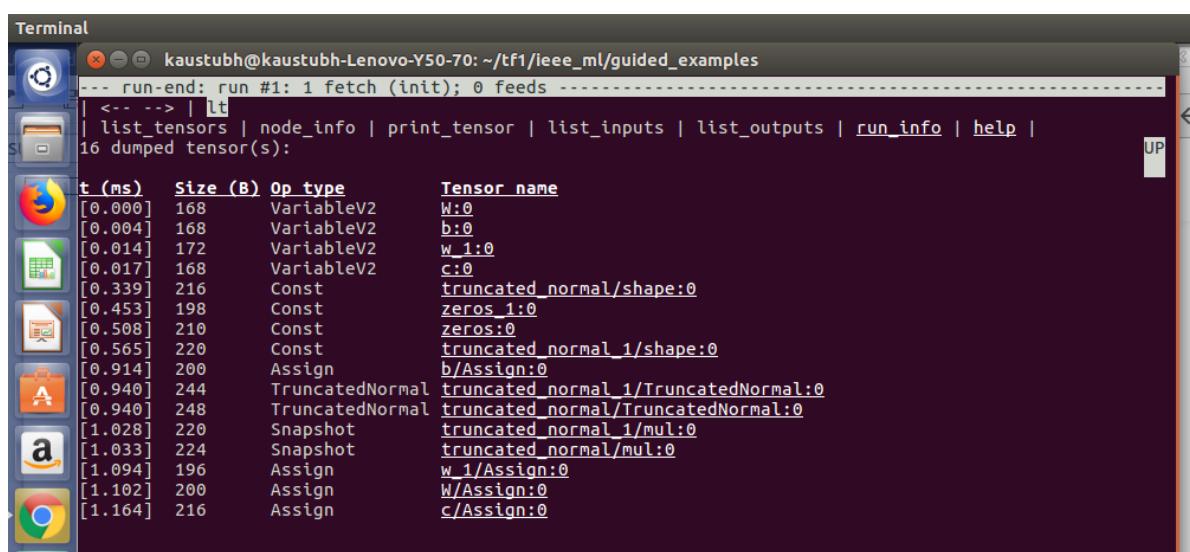


A screenshot of a terminal window titled "Terminal". The window shows the output of a "tfdbg> run" command. The output lists 16 dumped tensors with their names, sizes, and op types. The tensors include variables (VariableV2), constants (Const), and operations like TruncatedNormal and Assign. The terminal window has a dark background and a light-colored text area. A scroll bar is visible on the right side of the window.

| t (ms) | Size (B) | Op type | Tensor name |
|---------|----------|-----------------|--------------------------------------|
| [0.000] | 168 | VariableV2 | W:0 |
| [0.004] | 168 | VariableV2 | b:0 |
| [0.014] | 172 | VariableV2 | w_1:0 |
| [0.017] | 168 | VariableV2 | c:0 |
| [0.339] | 216 | Const | truncated_normal/shape:0 |
| [0.453] | 198 | Const | zeros_1:0 |
| [0.508] | 210 | Const | zeros:0 |
| [0.565] | 220 | Const | truncated_normal_1/shape:0 |
| [0.914] | 200 | Assign | b/Assign:0 |
| [0.940] | 244 | TruncatedNormal | truncated_normal_1/TruncatedNormal:0 |
| [0.940] | 248 | TruncatedNormal | truncated_normal/TruncatedNormal:0 |
| [1.028] | 220 | Snapshot | truncated_normal_1/mul:0 |
| [1.033] | 224 | Snapshot | truncated_normal/mul:0 |
| [1.094] | 196 | Assign | w_1/Assign:0 |
| [1.102] | 200 | Assign | W/Assign:0 |
| [1.164] | 216 | Assign | c/Assign:0 |

The above screenshot shows the intermediate tensors from the previous Session.run() call.

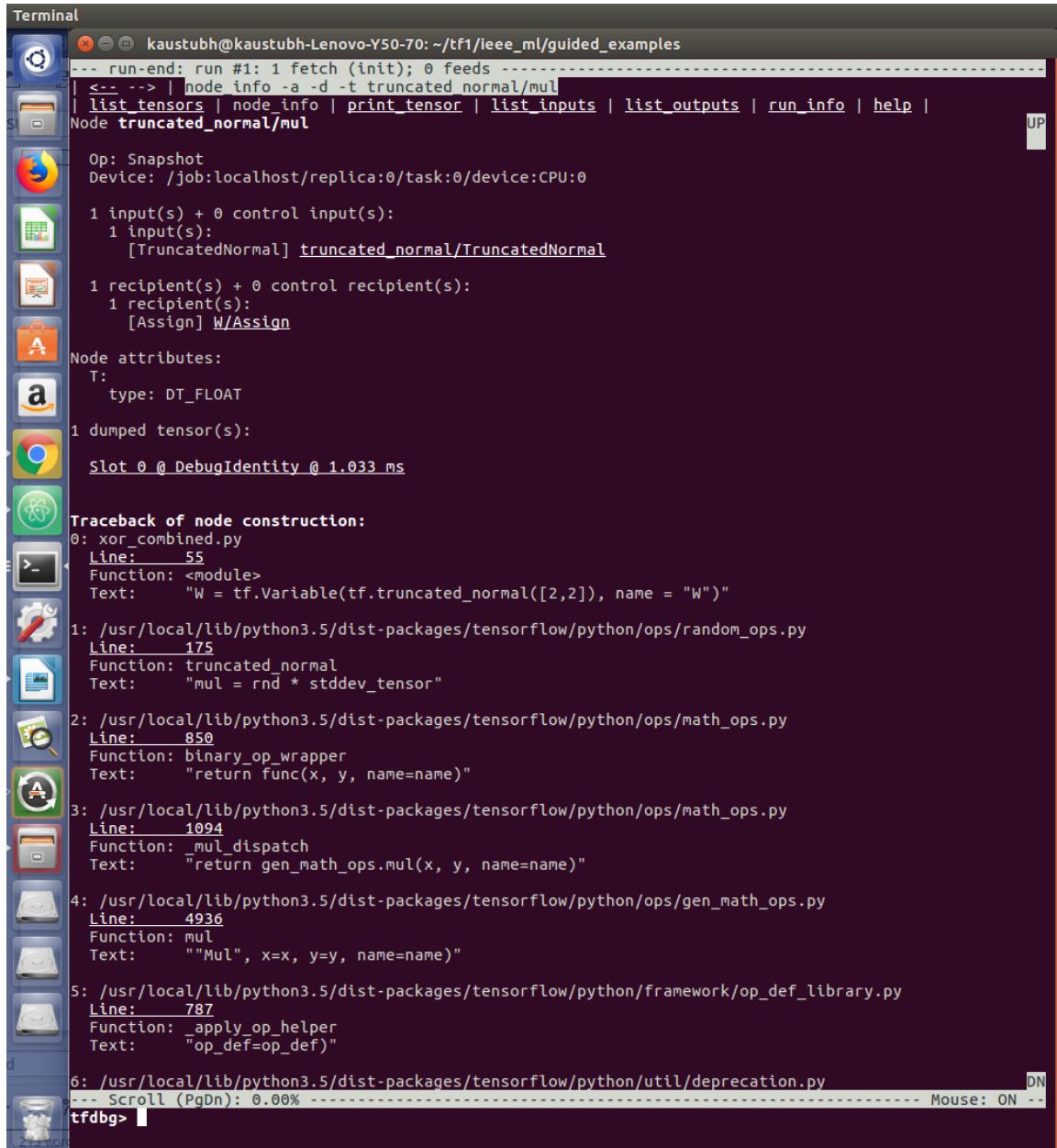
For one such tensor, truncated_normal/mul



A screenshot of a terminal window titled "Terminal". The window shows the output of a "tfdbg> run" command. The output lists 16 dumped tensors with their names, sizes, and op types. The tensors include variables (VariableV2), constants (Const), and operations like TruncatedNormal and Assign. The terminal window has a dark background and a light-colored text area. A scroll bar is visible on the right side of the window.

| t (ms) | Size (B) | Op type | Tensor name |
|---------|----------|-----------------|--------------------------------------|
| [0.000] | 168 | VariableV2 | W:0 |
| [0.004] | 168 | VariableV2 | b:0 |
| [0.014] | 172 | VariableV2 | w_1:0 |
| [0.017] | 168 | VariableV2 | c:0 |
| [0.339] | 216 | Const | truncated_normal/shape:0 |
| [0.453] | 198 | Const | zeros_1:0 |
| [0.508] | 210 | Const | zeros:0 |
| [0.565] | 220 | Const | truncated_normal_1/shape:0 |
| [0.914] | 200 | Assign | b/Assign:0 |
| [0.940] | 244 | TruncatedNormal | truncated_normal_1/TruncatedNormal:0 |
| [0.940] | 248 | TruncatedNormal | truncated_normal/TruncatedNormal:0 |
| [1.028] | 220 | Snapshot | truncated_normal_1/mul:0 |
| [1.033] | 224 | Snapshot | truncated_normal/mul:0 |
| [1.094] | 196 | Assign | w_1/Assign:0 |
| [1.102] | 200 | Assign | W/Assign:0 |
| [1.164] | 216 | Assign | c/Assign:0 |

Now, we can use the `node_info` option to check up the type and attributes of this graph node as shown



The screenshot shows a terminal window on a Linux desktop environment. The terminal output is as follows:

```
kaustubh@kaustubh-Lenovo-Y50-70: ~/tf1/ieee_ml/guided_examples
--- run-end: run #1: 1 fetch (init); 0 feeds -----
| <- -> | node_info -a -d -t truncated_normal/mul
| list_tensors | node_info | print_tensor | list_inputs | list_outputs | run_info | help |
Node truncated_normal/mul

Op: Snapshot
Device: /job:localhost/replica:0/task:0/device:CPU:0

1 input(s) + 0 control input(s):
  1 input(s):
    [TruncatedNormal] truncated_normal/TruncatedNormal

1 recipient(s) + 0 control recipient(s):
  1 recipient(s):
    [Assign] W/Assign

Node attributes:
  T:
    type: DT_FLOAT

1 dumped tensor(s):
  Slot 0 @ DebugIdentity @ 1.033 ms

Traceback of node construction:
0: xor_combined.py
  Line: 55
  Function: <module>
  Text: "W = tf.Variable(tf.truncated_normal([2,2]), name = "W")"

1: /usr/local/lib/python3.5/dist-packages/tensorflow/python/ops/random_ops.py
  Line: 175
  Function: truncated_normal
  Text: "mul = rnd * stddev_tensor"

2: /usr/local/lib/python3.5/dist-packages/tensorflow/python/ops/math_ops.py
  Line: 850
  Function: binary_op_wrapper
  Text: "return func(x, y, name=name)"

3: /usr/local/lib/python3.5/dist-packages/tensorflow/python/ops/math_ops.py
  Line: 1094
  Function: _mul_dispatch
  Text: "return gen_math_ops.mul(x, y, name=name)"

4: /usr/local/lib/python3.5/dist-packages/tensorflow/python/ops/gen_math_ops.py
  Line: 4936
  Function: mul
  Text: "'Mul", x=x, y=y, name=name)"

5: /usr/local/lib/python3.5/dist-packages/tensorflow/python/framework/op_def_library.py
  Line: 787
  Function: _apply_op_helper
  Text: "op_def=op_def)"

6: /usr/local/lib/python3.5/dist-packages/tensorflow/python/util/deprecation.py
--- Scroll (PgDn): 0.00% ----- Mouse: ON -- DN
tfdbg>
```

The *list_inputs* and *list_outputs* give the transitive inbound and outbound tensors of a given node.

```
kaustubh@kaustubh-Lenovo-Y50-70:~/tf1/ieee_ml/guided_examples
--> run: end; run #1: 1 fetch (init); 0 feeds -----
|--> | list outputs -c -r truncated_normal/mul
| list_tensors | node_info | print_tensor | list_inputs | list_outputs | run_info | help |
Recipients of node "truncated_normal/mul" (Depth limit = 20, control recipients included):
|- (1) WAssign
|- (2) (Ctrl) init
Legend:
(d): recursion depth = d.
(Ctrl): Control input.

--> Scroll (PgDn): 0.00% ----- Mouse: ON -->
tfdbs>
```

list_inputs

```
kaustubh@kaustubh-Lenovo-Y50-70:~/tf1/ieee_ml/guided_examples
--> run: end; run #1: 1 fetch (init); 0 feeds -----
|--> | list_inputs -c -r truncated_normal/mul
| list_tensors | node_info | print_tensor | list_inputs | list_outputs | run_info | help |
Inputs to node "truncated_normal/mul" (Depth limit = 20, control inputs included):
|- (1) truncated_normal/mul
|- (2) truncated_normal/mul
Legend:
(d): recursion depth = d.
(Ctrl): Control input.

--> Scroll (PgDn): 0.00% ----- Mouse: ON -->
tfdbs>
```

list out_puts

Also, conditional breakpoints feature of *tf_debug* can be used to let code run until certain cases/ conditions are satisfied on the graph.

In this case, let us consider the case the model runs until values like *inf* and *nan* are encountered. For this, in the command line enter;

```
tfdbs> run -f has_inf_or_nan
```

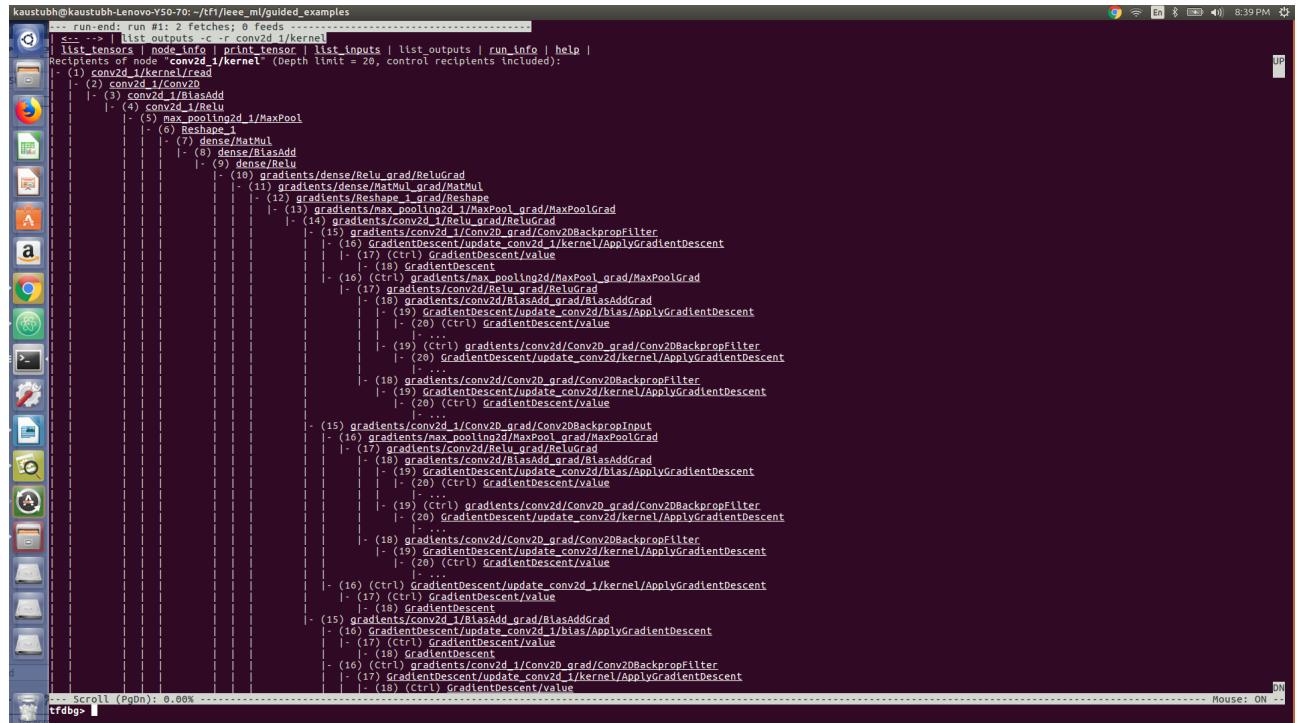
For this example, on xor_combined.py, all the epochs are run as XOR mapping using an ANN is relatively simple than image classification tasks and hence did not run into any issues.

```
kaustubh@kaustubh-Lenovo-Y50-70:~/tf1/ieee_ml/guided_examples
kaustubh@kaustubh-Lenovo-Y50-70:~/tf1/ieee_ml/guided_examples$ python3 xor_combined.py
2018-09-21 18:59:18.359206: I tensorflow/core/platform/cpu_feature_guard.cc:141] Your CPU supports instructions that this TensorFlow binary was not compiled to use: AVX2 FMA
^Z
[1]: Stopped python3 xor_combined.py
kaustubh@kaustubh-Lenovo-Y50-70:~/tf1/ieee_ml/guided_examples$ python2 xor_combined.py
2018-09-21 19:02:39.492652: I tensorflow/core/platform/cpu_feature_guard.cc:141] Your CPU supports instructions that this TensorFlow binary was not compiled to use: AVX2 FMA
^Z
[1]: Stopped python3 xor_combined.py
kaustubh@kaustubh-Lenovo-Y50-70:~/tf1/ieee_ml/guided_examples$ python3 xor_combined.py
2018-09-21 19:03:02.357818: I tensorflow/core/platform/cpu_feature_guard.cc:141] Your CPU supports instructions that this TensorFlow binary was not compiled to use: AVX2 FMA
Epoch: 0
y:
[[0.49984378]
 [0.85242045]
 [0.6522666]
 [0.9152757]]
W:
[-0.31868675  0.42915654]
[-0.01389174  1.1991655 ]
c:
[[0. 0.]
 [0. 0.8001354]
 [0. 0.0003775]
 [0. 0. -0.00031621]
 w:
 [-1.4329072]
 [1.4622812]
 b:
 [-0.000625]
 [9.273729e-05]
 [0.00039491]
 [-0.00035433]
 loss: 0.30757633
z[3]+ Stopped python3 xor_combined.py
kaustubh@kaustubh-Lenovo-Y50-70:~/tf1/ieee_ml/guided_examples$ python3 cnn_mnist.py
WARNING:tensorflow:From cnn_mnist.py:144: load_dataset (from tensorflow.contrib.learn.python.learn.datasets) is deprecated and will be removed in a future version.
It is recommended to use tf.data.
Please use tf.data.
WARNING:tensorflow:From /usr/local/lib/python3.5/dist-packages/tensorflow/contrib/learn/python/learn/datasets/_mnist_.py:80: load_mnist (from tensorflow.contrib.learn.python.learn.datasets.mnist) is deprecated and will be removed in a future version.
It is recommended to use tf.data.
Please use alternatives such as official/mnist/dataset.py from tensorflow/models.
WARNING:tensorflow:From /usr/local/lib/python3.5/dist-packages/tensorflow/contrib/learn/python/learn/datasets/mnist.py:300: read_data_sets (from tensorflow.contrib.learn.python.learn.datasets.mnist) is deprecated and will be removed in a future version.
It is recommended to use tf.data.
Please use alternatives such as official/mnist/dataset.py from tensorflow/models.
WARNING:tensorflow:From /usr/local/lib/python3.5/dist-packages/tensorflow/contrib/learn/python/learn/datasets/mnist.py:260: maybe_download (from tensorflow.contrib.learn.python.learn.datasets.base) is deprecated and will be removed in a future version.
```

We shall see this debugging aspect a little more in detail for the `cnn_mnist.py` case.

`cnn_mnist.py`

For the node: `conv_2d_1` kernel the `list_outputs` are as follows:



```
-- run-end: run #1: 2 fetches; 0 feeds -----
... --> | list_outputs -c -r conv2d_1/kernel
list_tensors node_info | print_tensor | list_inputs | list_outputs | run_info | help |
Recipients of node_info: conv2d_1/kernel (Depth limit = 20, control recipients included):
- (1) conv2d_1/Kernel/seed
  |- (2) conv2d_1/Conv2D
    |- (3) conv2d_1/BiasAdd
      |- (4) conv2d_1/Relu
        |- (5) max_pooling2d_1/MaxPool
          |- (6) reshape_1
            |- (7) dense/MatMul
              |- (8) dense/BiasAdd
                |- (9) dense/Relu
                  |- (10) gradients/dense/Relu_grad/ReluGrad
                    |- (11) gradients/dense/MatMul/grad/MatMul
                      |- (12) gradients/Reshape_1_grad/Reshape
                        |- (13) gradients/max_pooling2d_1/MaxPool_grad/MaxPoolGrad
                          |- (14) gradients/conv2d_1/Relu_grad/ReluGrad
                            |- (15) gradients/conv2d_1/Conv2D_grad/Conv2DBackpropFilter
                              |- (16) gradients/conv2d_1/Conv2D_grad/Conv2DBackpropFilter
                                |- (17) (ctrl) GradientDescent/value
                                  ...
                                  |- (18) (ctrl) GradientDescent/value
                                  |- (19) gradients/conv2d_1/Conv2D_grad/Conv2DBackpropFilter
                                    |- (20) (ctrl) GradientDescent/value
                                  ...
                                  |- (16) (ctrl) gradients/max_pooling2d_1/MaxPool_grad/MaxPoolGrad
                                    |- (17) gradients/conv2d_1/Relu_grad/ReluGrad
                                      ...
                                      |- (19) GradientDescent/update_conv2d/bias/ApplyGradientDescent
                                        |- (20) (ctrl) GradientDescent/value
                                        ...
                                        |- (19) gradients/conv2d_1/Conv2D_grad/Conv2DBackpropFilter
                                          |- (20) (ctrl) GradientDescent/update_conv2d/kernel/ApplyGradientDescent
                                            ...
                                            |- (18) gradients/conv2d_1/Conv2D_grad/Conv2DBackpropFilter
                                              |- (19) GradientDescent/update_conv2d/kernel/ApplyGradientDescent
                                                |- (20) (ctrl) GradientDescent/value
                                              ...
                                              |- (15) gradients/max_pooling2d_1/MaxPool_grad/MaxPoolGrad
                                                ...
                                                |- (17) gradients/conv2d_1/Relu_grad/ReluGrad
                                                  ...
                                                  |- (19) gradients/conv2d_1/BiasAdd_grad/BiasAddGrad
                                                    ...
                                                    |- (16) GradientDescent/update_conv2d_1/bias/ApplyGradientDescent
                                                      ...
                                                      |- (17) (ctrl) GradientDescent/value
                                                      ...
                                                      |- (16) (ctrl) gradients/conv2d_1/Conv2D_grad/Conv2DBackpropFilter
                                                        ...
                                                        |- (17) (ctrl) GradientDescent/value
                                                        ...
                                                        |- (18) (ctrl) GradientDescent/value
                                                        ...
                                                        |- (16) (ctrl) gradients/conv2d_1/Conv2D_grad/Conv2DBackpropFilter
                                                          ...
                                                          |- (17) (ctrl) GradientDescent/value
                                                          ...
                                                          |- (18) (ctrl) GradientDescent/value
...
-- Scroll (PgDn): 0.00% ----- Mouse: ON --
tfdbg>
```

The command:

```
>tfdbg run -f has_inf_or_nan
```

was run and there was no such tensor which had these values as the entire training cycle completed without halting at any `Session.run` call.

Also, regex search can be used to find desired tensors in the CLI debug window.

In the below window; I have searched for “drop” and all “drop” occurrences are highlighted.

```
tfdbg> (drop) ---> Searching for the regular expression "drop"
```

```

kaustubh@kaustubh-Lenovo-Y50-70:~/tf/ieee_ml/guided_examples
-- run-end: run #1: 2 fetches; 0 feeds --
lits_tensors | node_info | print_tensor | list_inputs | list_outputs | run_info | help |
[1.646] 252 Const gradients/dropout/Dropout/div_grad/Shape:0
[1.773] 227 IsVariableInitialized global_step/IsVariableInitialized:0
[1.792] 3.33k Identity conv2d/kernel/read:0
[1.804] 4.09k Identity dense_1/bias/read:0
[1.825] 40.20k VariableV2 dense_1/kernel/read:0
[2.295] 222 Const GradientDescent/learning_rate:0
[2.326] 224 RefSwitch global_step/cond/read/switch1:0
[2.332] 228 VariableV2 dense_1/bias:0
[2.428] 371 RandomShuffleQueueV2 enqueue_input/random_shuffle_queue:0
[2.431] 419 Cond enqueue_input/random_shuffle_queue/fraction_over_250_of_750_full/tags:0
[2.617] 238 Identity enqueue_input/random_shuffle_queue/Size:0
[2.900] 242 QueueSizeV2 dense_1/kernel/read:0
[2.993] 40.72k Identity enqueue_input/Maximum/x:0
[3.144] 210 Const enqueue_input/Maximum/y:0
[3.202] 202 Cast conv2d/1/kernel/read:0
[3.433] 208.22k Identity enqueue_input/mul/v0
[3.510] 202 Const enqueue_input/sub:b0
[3.562] 198 Sub loss/tags:0
[3.658] 182 Const enqueue_input/Maximum/b
[3.774] 206 Maximum global_step/Initializer/zeros:0
[3.844] 226 Const enqueue_input/random_uniform/RandomUniform:0
[3.899] 206 Const Reshape/shape:0
[3.912] 200 Cast enqueue_input/Cast:0
[4.019] 202 Const Reshape/_1/shape:0
[4.106] 159 Pow enqueue_input/keep_prob:0
[4.134] 214 Const dropout/random/keep_prob:0
[4.182] 418 ScalarSummary enqueue_input/enqueue_input/random_shuffle_queue/fraction_over_250_of_750_full:0
[4.262] 232 Const random_shuffle_queue/DequeueMany/n:0
[4.371] 250 Const sparse_softmax_cross_entropy_loss/Const_1:0
[4.401] 252 Const sparse_softmax_cross_entropy_loss/Const_2:0
[4.570] 243 Const sparse_softmax_cross_entropy_loss/Greater:0
[4.674] 218 Switch global_step/cond/switch_1:1
[4.783] 208 Merge global_step/cond/Merge:1
[4.860] 212 Merge global_step/cond/Merge:0
[4.938] 198 ScatterNd global_step/keep:0
[5.041] 1.81k QueueDequeueManyV2 random_shuffle_queue/DequeueMany:0
[8.815] 630 QueueDequeueManyV2 random_shuffle_queue/DequeueMany:2
[9.248] 400.24k Snapshot dropout/dropout/random_uniform/mul:0
[9.305] 306.48k QueueDequeueManyV2 random_shuffle_queue/DequeueMany:1
[11.197] 400.23k Snapshot dropout/dropout/random_uniform:0
[12.068] 400.23k Add attention/softmax/dot:0
[12.890] 400.21k Floor dropout/dropout/add:0
[19.636] 12.25M VariableV2 dropout/dropout:0
[43.140] 9.57M Conv2D dense/kernel/read:0
[103.511] 10.25M Identity conv2d/1/bias/read:0
[113.581] 9.57M BiasAdd conv2d/1/bias:0
[106.756] 9.57M Relu conv2d/Relu:0
[208.717] 2.39M MaxPool max_pooling2d/MaxPool:0
[283.754] 4.79M Conv2D conv2d/1/Conv2D:0
[4.793] 4.79M BiasAdd conv2d/1/BiasAdd:0
[324.443] 1.20M Relu conv2d/1/Relu:0
[341.525] 1.20M MaxPool max_pooling2d/1/MaxPool:0
[346.855] 1.20M Reshape Reshape_1:0
[363.903] 400.19k MatMul dense/MatMul:0
-- Scroll (PgDn/PgUp): 10.71% ----- Mouse: ON --

```

Now we shall see a way to step through the nodes of graph one-by-one in a manner analogous to procedural languages debuggers like GDB and PDB.

tfdbg> invoke stepper

tfdbg> s ---> Call once for stepping through each node in the graph.

```

kaustubh@kaustubh-Lenovo-Y50-70:~/tf/ieee_ml/guided_examples
-- Node Stepper: run #2: 2 fetches; 0 feeds -----
| <-> [1t] Topologically-sorted transitively Input(s) and fetch(es):
-->(1 / 201) [ ] gradients/shape
(2 / 201) [ ] sparse_softmax_cross_entropy_loss/assert_broadcastable/static_scalar_check_success
(3 / 201) [ ] sparse_softmax_cross_entropy_loss/Equal:y
(4 / 201) [ ] sparse_softmax_cross_entropy_loss/Greater:y
(5 / 201) [ ] sparse_softmax_cross_entropy_loss/num_present/ones_like/Const
(6 / 201) [ ] sparse_softmax_cross_entropy_loss/num_present/zeros_like/Const
(7 / 201) [ ] sparse_softmax_cross_entropy_loss/ones_like/Const
(8 / 201) [ ] sparse_softmax_cross_entropy_loss/Const_1
(9 / 201) [ ] sparse_softmax_cross_entropy_loss/num_present/broadcast_weights/assert_broadcastable/static_scalar_check_success
(10 / 201) [ ] sparse_softmax_cross_entropy_loss/num_present/broadcast_weights/ones_like/Shape
(11 / 201) [ ] sparse_softmax_cross_entropy_loss/num_present/broadcast_weights/ones_like/Shape
(12 / 201) [ ] sparse_softmax_cross_entropy_loss/num_present/broadcast_weights/ones_like/Shape
(13 / 201) [ ] sparse_softmax_cross_entropy_loss/num_present/broadcast_weights/ones_like/Shape
(14 / 201) [ ] sparse_softmax_cross_entropy_loss/zeros_like/Shape
(15 / 201) [ ] sparse_softmax_cross_entropy_loss/ones_like/Shape
(16 / 201) [ ] sparse_softmax_cross_entropy_loss/ones_like/Shape
(17 / 201) [ ] sparse_softmax_cross_entropy_loss/Const_1
(18 / 201) [ ] sparse_softmax_cross_entropy_loss/num_present/ones_like
(19 / 201) [ ] sparse_softmax_cross_entropy_loss/num_present/ones_like
(20 / 201) [ ] sparse_softmax_cross_entropy_loss/num_present/Const
(21 / 201) [ ] GradientDescent/learning_rate
(22 / 201) [ ] gradients/sparse_softmax_cross_entropy_loss/Sum_1_grad/Const
(23 / 201) [ ] conv2d/1/bias/read
(24 / 201) [ ] gradients/sparse_softmax_cross_entropy_loss/Sum_1_grad/Reshape/shape
(25 / 201) [ ] gradients/dropout/random_uniform/mul
(26 / 201) [ ] dropout/dropout/random_uniform/mul
(27 / 201) [ ] dense_1/bias:0
(28 / 201) [ ] dense_1/kernel/read
(29 / 201) [ ] random_shuffle_queue/DequeueMany:n
(30 / 201) [ ] Reshape_1/shape
(31 / 201) [ ] gradients/grad_y:0
(32 / 201) [ ] gradients/fill
(33 / 201) [ ] conv2d/1/bias:0
(34 / 201) [ ] conv2d/kernel/read
(35 / 201) [ ] gradients/sparse_softmax_cross_entropy_loss/Sum_1_grad/Reshape/shape
(36 / 201) [ ] enqueue_input/random_shuffle_queue
(37 / 201) [ ] random_shuffle_queue/DequeueMany:n
(38 / 201) [ ] gradients/sparse_softmax_cross_entropy_loss/sum_grad/Const
(39 / 201) [ ] gradients/sparse_softmax_cross_entropy_loss/xentropy/xentropy_grad/ExpandDims/dim
(40 / 201) [ ] gradients/sparse_softmax_cross_entropy_loss/xentropy/xentropy_grad/ExpandDims/dim
(41 / 201) [ ] conv2d/bias/read
(42 / 201) [ ] dense/kernel/read
(43 / 201) [ ] dense/kernel/read
(44 / 201) [ ] gradients/sparse_softmax_cross_entropy_loss/sum_grad/Reshape/shape
(45 / 201) [ ] gradients/dropout/dropout/div_grad/shape:1
(46 / 201) [ ] gradients/dropout/dropout/div_grad/shape
(47 / 201) [ ] gradients/dropout/dropout/div_grad/BroadcastGradArgs
(48 / 201) [ ] gradients/sparse_softmax_cross_entropy_loss/Mul_grad/shape:1
(49 / 201) [ ] gradients/sparse_softmax_cross_entropy_loss/sum_grad/Reshape/shape
(50 / 201) [ ] dense/bias/read
(51 / 201) [ ] dense_1/kernel
(52 / 201) [ ] dense_1/kernel/read
(53 / 201) [ ] Reshape/shape
(54 / 201) [ ] Reshape
(55 / 201) [ ] gradients/conv2d/Conv2D/orad/shape:N
-- Scroll (PgDn): 0.00% ----- Mouse: ON --

```

The above screenshot shows the CLI after running the *invoke stepper*.

Traversed 23 times to the 23rd tensor (node). Arrived at tensor conv2d_1/bias.

```
Terminal kaustubh@kaustubh-Lenovo-Y50-70: ~/tf1/ieee_ml/guided_examples
--- Node Stepper: run #2: 2 fetches; 0 feeds -----
| <- -> | s
| (21 / 201) [ H ] GradientDescent/learning_rate
| (22 / 201) [ H ] gradients/sparse_softmax_cross_entropy_loss/Sum_1_grad/Const
-->(23 / 201) [ H ] conv2d_1/bias
| (24 / 201) [ ] conv2d_1/bias/read
| (25 / 201) [ ] gradients/sparse_softmax_cross_entropy_loss/Sum_1_grad/Reshape/shape
Continued to conv2d_1/bias:
Stepper used feeds:
(No feeds)

Tensor "conv2d_1/bias":
  dtype: float32
  shape: (64,)

array([-6.4245737e-03, -1.1049911e-03, -2.8435481e-03, -6.0856170e-03, 4.4578407e-03, -2.9437926e-03,
       1.1797058e-03, -3.3700862e-04, 4.4678403e-03, 7.9403818e-04, -1.3935991e-03, 2.3202647e-03,
       5.4761763e-03, 1.2291918e-03, -3.6602267e-03, -1.5621104e-03, -3.4348869e-03, 2.2799787e-03,
      -1.6903636e-03, 7.9052988e-03, 4.7243210e-03, 4.1664601e-03, 7.6617762e-03, 1.3869540e-03,
       1.2804556e-03, 5.9276596e-03, 1.9799273e-03, -3.6244935e-03, -2.1704400e-03, -9.4626172e-03,
      6.4960658e-03, 3.4955924e-03, 6.6145868e-03, -1.5650952e-03, -3.9124405e-03, 5.1908474e-04,
       3.0861902e-03, 4.5332010e-03, -6.9009978e-04, 1.8244556e-03, -1.8225196e-03, -4.2091244e-05,
      5.5355150e-03, 2.1685592e-03, -3.3132746e-03, -2.4143842e-03, -1.4805236e-03, -1.2613695e-04,
       7.0909485e-03, 2.3233686e-03, -1.1860991e-03, -2.6365105e-04, -1.4719635e-05, 1.6924310e-04,
      5.6557666e-04, -4.1795475e-03, -1.2175994e-03, 5.5604633e-03, 8.2645088e-04, -7.4623473e-04,
       1.8561778e-03, -1.8244114e-04, 5.0964090e-03, 2.7790812e-03], dtype=float32)
```

To modify the value of a given tensor at a step stage while preserving the values of all other tensors we use;

`tfdbg> inject "tensor_name" "value_to_be_given"`

Executed:

`tfdbg> inject conv2d_1/bias np.zeros(64,)`

Obtained:

```
Terminal kaustubh@kaustubh-Lenovo-Y50-70: ~/tf1/ieee_ml/guided_examples
--- Node Stepper: run #2: 2 fetches; 0 feeds -----
| <- -> | inject conv2d_1/bias np.zeros(64,)
| Injected value "np.zeros(64,)"
| to tensor "conv2d_1/bias:0":
Tensor "conv2d_1/bias:0":
  dtype: float64
  shape: (64,)

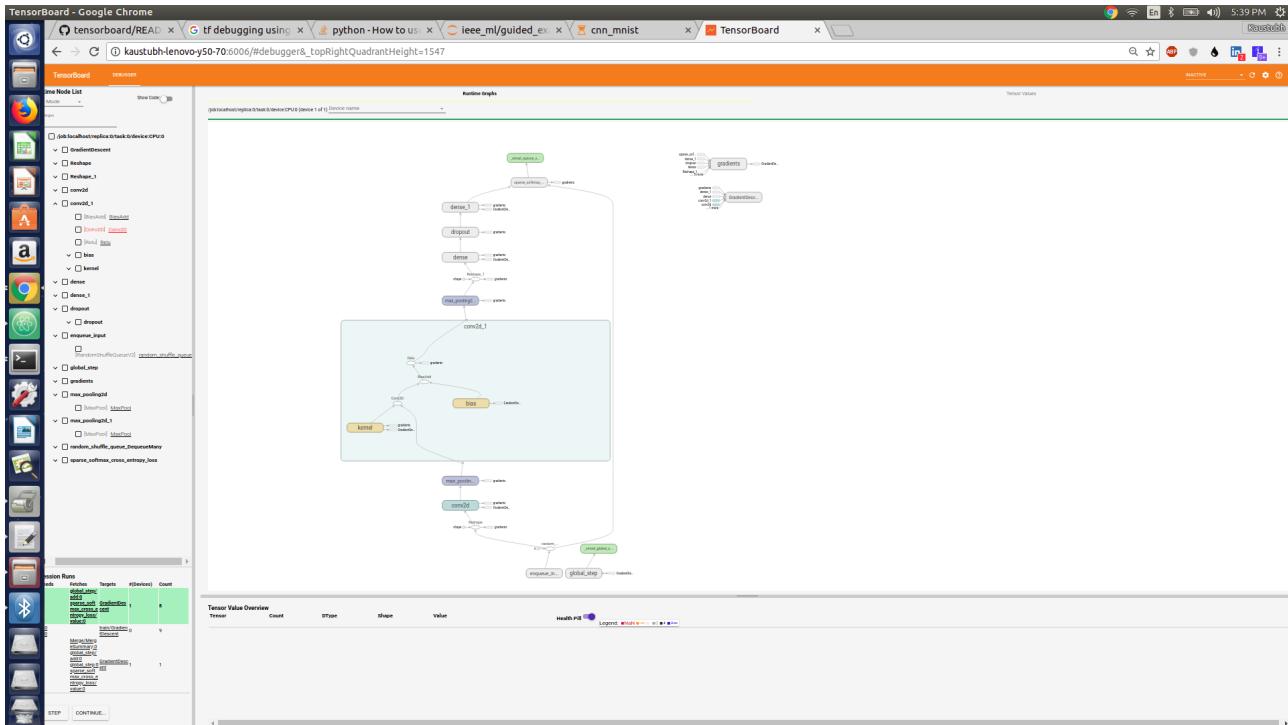
array([0., 0., 0., 0., 0., 0., 0., 0., 0., 0., 0., 0., 0., 0., 0., 0.,
       0., 0., 0., 0., 0., 0., 0., 0., 0., 0., 0., 0., 0., 0., 0., 0.,
       0., 0., 0., 0., 0., 0., 0., 0., 0., 0., 0., 0., 0., 0., 0., 0.,
       0., 0., 0., 0., 0., 0., 0., 0., 0., 0., 0., 0., 0., 0., 0., 0., 0.,
```

This command can be used to check if any specific tensor causes issues in a specific run, its value can be changed and set to a meaningful value while leaving all other tensors in the Session.run call unchanged.

Tensorboard debugger – Not supported on Windows yet!!

Tensorboard offers a GUI plugin for debugging. In the CLI mode, we have to traverse the computational graph to go to any node of interest.

The following screenshot is the layout of the Tensorboard Debugger session for the file `cnn_mnist.py`.

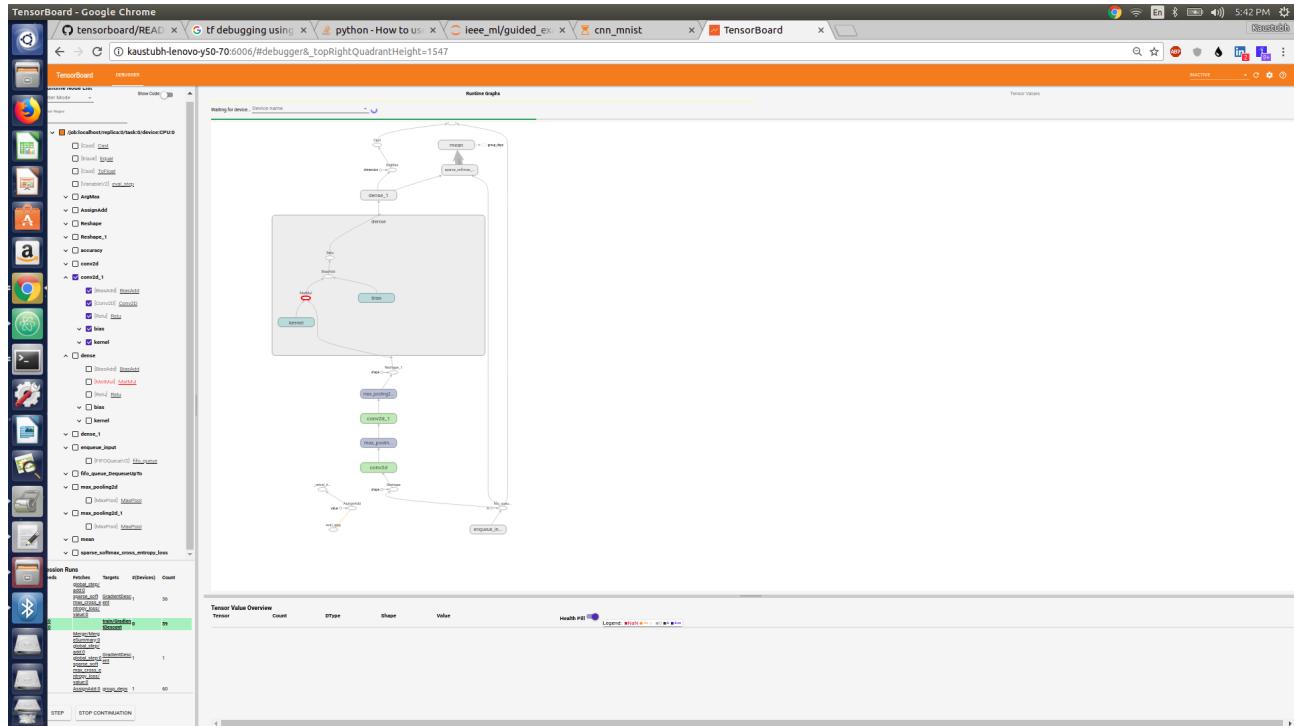


On running the file; `cnn_mnist.py` either on Jupyter notebook or as a .py file, a computatoinal graph is generated initially. Any node can be double-clicked to magnify and analyse the various elements of the magnified node. Here, the node `dense conv2d_1` is magnified and one can see the convolution operation, addition of bias in the node.

To move to next node use the STEP button in the bottom-left corner. Also, the CONTINUE button shall help you to conditionally run the Session calls.

To traverse to a particular node, desired node can be right-clicked and select *Continue to*, and the graph computation occur until you reach the desired node.

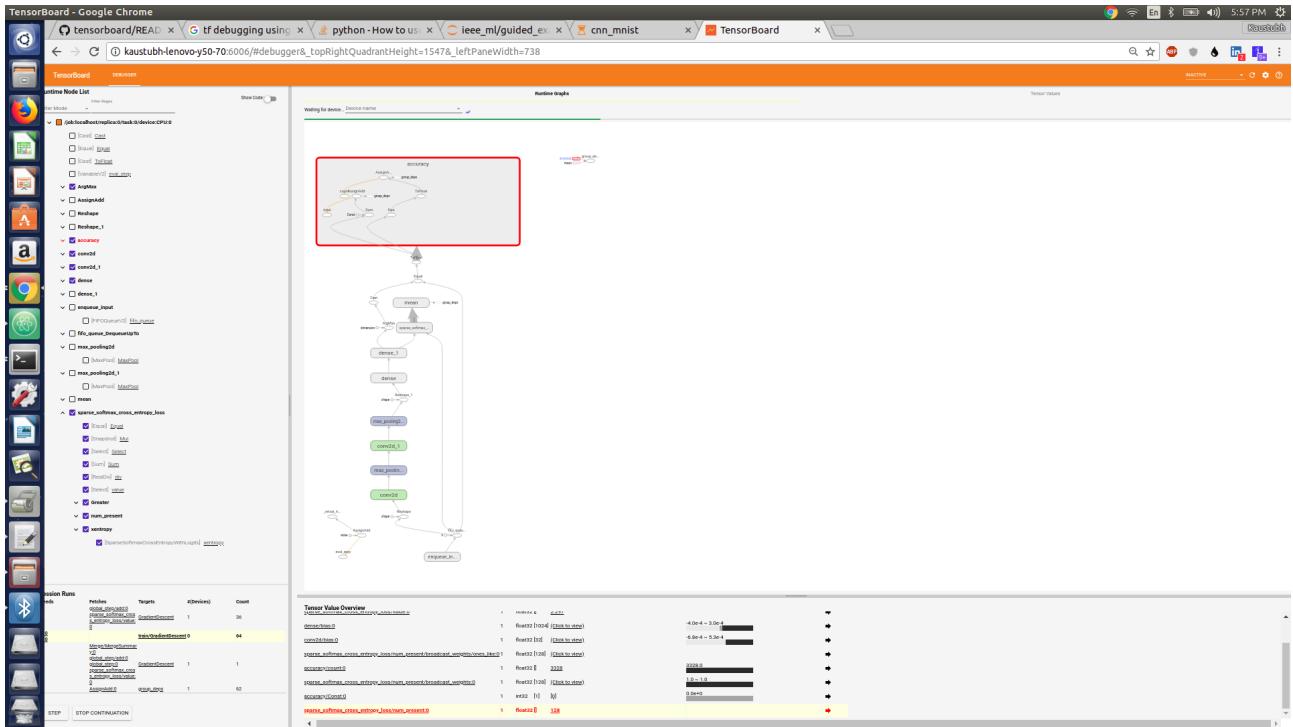
In the following example, I reached the dense node by clicking *Continue to* after right-clicking.



Finally, I used the STEP functionality to traverse to the accuracy node and used the *Continue to* option for generating the computational graph.

Once the Session.run() call execution is paused, the values of tensors for all the selected nodes is displayed in the bottom half of the screen. Each tensor is also attributed with a *health pill* which visualises the proportion of values within the tensor that fall under each of the six categories noted in the legend. A user might use health pills to for instance pinpoint nodes that are culprits for producing undesired values (such as infinity & NaN).

The following screenshot illustrates this.



We have covered debugging on Tensorboard for our example in a brief manner.

However, please refer to the document;

<https://github.com/tensorflow/tensorboard/tree/master/tensorboard/plugins/debugger>

for detailed instructions for using the Tensorboard debugger.

The below *SUMMARY MATRIX* gives the Tensorflow functionalites of visualizer and debugger that are enabled with each file in the *ieee_ml* directory.

| File | Tensorboard – visualization | Tensorboard – Debugger | CLI Debugger |
|--|-----------------------------|------------------------|--------------|
| ./iee_ml/ | Tensorboard – visualization | Tensorboard – Debugger | CLI Debugger |
| guided_examples/cnn_mnist.ipynb | No | Yes | No |
| guided_examples/cnn_mnist_no_debugger.ipynb | No | No | No |
| guided_examples/kmeans.ipynb | No | No | |
| guided_examples/nearest_neighbor.ipynb | No | No | No |
| guided_examples/mnist_hyperparameter.ipynb | Yes – hyperparameter search | No | No |
| guided_examples/xor_combined.ipynb | Yes | No | No |
| guided_examples/cnn_mnist.py | No | Yes | Yes |
| guided_examples/cnn_mnist_no_debugger.ipynb | No | No | No |
| guided_examples/kmeans.py | No | No | Yes |
| guided_examples/nearest_neighbor.py | No | No | Yes |
| guided_examples/mnist_hyperparameter.py | Yes – hyperparameter search | No | No |
| guided_examples/xor_combined.py | Yes | No | Yes |
| problem_sets/hdr_om/ ALL FILES | No | No | No |
| problem_sets/hdr_tf/handwritten_digits_recognition_cnn_5layer.ipynb | Yes | No | No |
| problem_sets/hdr_tf/handwritten_digits_recognition_cnn_5layer_solution.ipynb | No | No | No |
| problem_sets/hdr_tf/handwritten_digits_recognition_cnn_5layer.py | Yes | No | No |
| problem_sets/hdr_tf/handwritten_digits_recognition_cnn_5layer_solution.py | No | No | No |

| | | | |
|-----------------------------|----|----|----|
| basics_directory/ ALL FILES | No | No | No |
|-----------------------------|----|----|----|