Create Keras Wide-and-Deep model

This notebook illustrates:

1. Creating a model using Keras. This requires TensorFlow 2.1

In [1]:

```
# Ensure the right version of Tensorflow is installed.
!pip freeze | grep tensorflow==2.1
```

In [2]:

```
# change these to try this notebook out
BUCKET = 'cloud-training-demos-ml'
PROJECT = 'cloud-training-demos'
REGION = 'us-central1'
```

In [3]:

```
import os
os.environ['BUCKET'] = BUCKET
os.environ['PROJECT'] = PROJECT
os.environ['REGION'] = REGION
```

In [4]:

```
%%bash
if ! gsutil ls | grep -q gs://${BUCKET}/; then
  gsutil mb -l ${REGION} gs://${BUCKET}
fi
```

```
Creating gs://cloud-training-demos-ml/...
ServiceException: 409 A Cloud Storage bucket named 'cloud-training-demos-ml' alr
eady exists. Try another name. Bucket names must be globally unique across all G
oogle Cloud projects, including those outside of your organization.

---------------------------------------------------------------------------
CalledProcessError                        Traceback (most recent call last)
<ipython-input-4-6b1d45d375e6> in <module>
----> 1 get_ipython().run_cell_magic('bash', '', 'if ! gsutil ls | grep -q gs://
${BUCKET}/; then\n  gsutil mb -l ${REGION} gs://${BUCKET}\nfi\n')

/opt/conda/lib/python3.7/site-packages/IPython/core/interactiveshell.py in run_c
ell_magic(self, magic_name, line, cell)
   2401             with self.builtin_trap:
   2402                 args = (magic_arg_s, cell)
-> 2403                 result = fn(*args, **kwargs)
   2404             return result
   2405 

/opt/conda/lib/python3.7/site-packages/IPython/core/magics/script.py in named_sc
ript_magic(line, cell)
    140             else:
    141                 line = script
--> 142             return self.shebang(line, cell)
    143 
    144         # write a basic docstring:

/opt/conda/lib/python3.7/site-packages/decorator.py in fun(*args, **kw)
    230             if not kwsyntax:
```

```
    231                 args, kw = fix(args, kw, sig)
--> 232             return caller(func, *(extras + args), **kw)
    233     fun.__name__ = func.__name__
    234     fun.__doc__ = func.__doc__

/opt/conda/lib/python3.7/site-packages/IPython/core/magic.py in <lambda>(f, *a,
 **k)
    185     # but it's overkill for just that one bit of state.
    186     def magic_deco(arg):
--> 187         call = lambda f, *a, **k: f(*a, **k)
    188 
    189         if callable(arg):

/opt/conda/lib/python3.7/site-packages/IPython/core/magics/script.py in shebang
(self, line, cell)
    243             sys.stderr.flush()
    244         if args.raise_error and p.returncode!=0:
--> 245             raise CalledProcessError(p.returncode, cell, output=out, std
err=err)
    246 
    247     def _run_script(self, p, cell, to_close):

CalledProcessError: Command 'b'if ! gsutil ls | grep -q gs://${BUCKET}/; then\n
gsutil mb -l ${REGION} gs://${BUCKET}\nfi\n'' returned non-zero exit status 1.
```

In [ ]:

```
%%bash
ls *.csv
```

Create Keras model

First, write an input_fn to read the data.

In [7]:

```
import shutil
import numpy as np
import tensorflow as tf
print(tf.__version__)
```

```
2.3.3
```

In [8]:

```
# Determine CSV, label, and key columns
CSV_COLUMNS = 'weight_pounds,is_male,mother_age,plurality,gestation_weeks,key'.s
LABEL_COLUMN = 'weight_pounds'
KEY_COLUMN = 'key'

# Set default values for each CSV column. Treat is_male and plurality as strings
DEFAULTS = [[0.0], ['null'], [0.0], ['null'], [0.0], ['nokey']]
```

In [9]:

```
def features_and_labels(row_data):
    for unwanted_col in ['key']:
        row_data.pop(unwanted_col)
    label = row_data.pop(LABEL_COLUMN)
    return row_data, label  # features, label

# load the training data
def load_dataset(pattern, batch_size=1, mode=tf.estimator.ModeKeys.EVAL):
  dataset = (tf.data.experimental.make_csv_dataset(pattern, batch_size, CSV_COLU
             .map(features_and_labels) # features, label
             )
  if mode == tf.estimator.ModeKeys.TRAIN:
        dataset = dataset.shuffle(1000).repeat()
  dataset = dataset.prefetch(1) # take advantage of multi-threading; 1=AUTOTUNE
  return dataset
```

Next, define the feature columns. mother_age and gestation_weeks should be numeric. The others (is_male, plurality) should be categorical.

In [11]:

```
## Build a Keras wide-and-deep model using its Functional API
def rmse(y_true, y_pred):
    return tf.sqrt(tf.reduce_mean(tf.square(y_pred - y_true)))

# Helper function to handle categorical columns
def categorical_fc(name, values):
    orig = tf.feature_column.categorical_column_with_vocabulary_list(name, value
    wrapped = tf.feature_column.indicator_column(orig)
    return orig, wrapped

def build_wd_model(dnn_hidden_units = [64, 32], nembeds = 3):
    # input layer
    deep_inputs = {
        colname : tf.keras.layers.Input(name=colname, shape=(), dtype='float32')
           for colname in ['mother_age', 'gestation_weeks']
    }
    wide_inputs = {
        colname : tf.keras.layers.Input(name=colname, shape=(), dtype='string')
           for colname in ['is_male', 'plurality']
    }
    inputs = {**wide_inputs, **deep_inputs}

    # feature columns from inputs
    deep_fc = {
        colname : tf.feature_column.numeric_column(colname)
           for colname in ['mother_age', 'gestation_weeks']
    }
    wide_fc = {}
    is_male, wide_fc['is_male'] = categorical_fc('is_male', ['True', 'False', 'U
    plurality, wide_fc['plurality'] = categorical_fc('plurality',
                      ['Single(1)', 'Twins(2)', 'Triplets(3)',
                       'Quadruplets(4)', 'Quintuplets(5)','Multiple(2+)'])

    # bucketize the float fields. This makes them wide
    age_buckets = tf.feature_column.bucketized_column(deep_fc['mother_age'],
                                                       boundaries=np.arange(15,45,
    wide_fc['age_buckets'] = tf.feature_column.indicator_column(age_buckets)
    gestation_buckets = tf.feature_column.bucketized_column(deep_fc['gestation_w
                                                       boundaries=np.arange(17,47,
    wide_fc['gestation_buckets'] = tf.feature_column.indicator_column(gestation_

    # cross all the wide columns. We have to do the crossing before we one-hot e
    crossed = tf.feature_column.crossed_column(
        [is_male, plurality, age_buckets, gestation_buckets], hash_bucket_size=2
    deep_fc['crossed_embeds'] = tf.feature_column.embedding_column(crossed, nemb

    # the constructor for DenseFeatures takes a list of numeric columns
    # The Functional API in Keras requires that you specify: LayerConstructor()(
    wide_inputs = tf.keras.layers.DenseFeatures(wide_fc.values(), name='wide_inp
    deep_inputs = tf.keras.layers.DenseFeatures(deep_fc.values(), name='deep_inp

    # hidden layers for the deep side
    layers = [int(x) for x in dnn_hidden_units]
    deep = deep_inputs
    for layerno, numnodes in enumerate(layers):
        deep = tf.keras.layers.Dense(numnodes, activation='relu', name='dnn_{}'.
    deep_out = deep

    # linear model for the wide side
    wide_out = tf.keras.layers.Dense(10, activation='relu', name='linear')(wide_

    # concatenate the two sides
    both = tf.keras.layers.concatenate([deep_out, wide_out], name='both')

    # final output is a linear activation because this is regression
    output = tf.keras.layers.Dense(1, activation='linear', name='weight')(both)
    model = tf.keras.models.Model(inputs, output)
    model.compile(optimizer='adam', loss='mse', metrics=[rmse, 'mse'])
    return model

print("Here is our Wide-and-Deep architecture so far:\n")
model = build_wd_model()
print(model.summary())
```

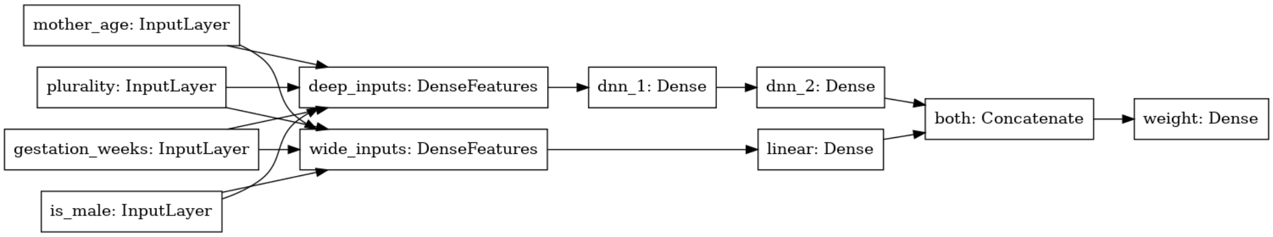
```
Here is our Wide-and-Deep architecture so far:

Model: "functional_3"
________________________________________________________________________________
__________________
Layer (type)                    Output Shape         Param #     Connected to
================================================================================
==================
gestation_weeks (InputLayer)    [(None,)]            0
________________________________________________________________________________
__________________
is_male (InputLayer)            [(None,)]            0
________________________________________________________________________________
__________________
mother_age (InputLayer)         [(None,)]            0
________________________________________________________________________________
__________________
plurality (InputLayer)          [(None,)]            0
________________________________________________________________________________
__________________
deep_inputs (DenseFeatures)     (None, 5)            60000       gestation_weeks
[0][0]
                                                                 is_male[0][0]
                                                                 mother_age[0]
[0]
                                                                 plurality[0][0]
________________________________________________________________________________
__________________
dnn_1 (Dense)                   (None, 64)           384         deep_inputs[0]
[0]
________________________________________________________________________________
__________________
wide_inputs (DenseFeatures)     (None, 71)           0           gestation_weeks
[0][0]
                                                                 is_male[0][0]
                                                                 mother_age[0]
[0]
                                                                 plurality[0][0]
_________________________________________________________________________________
__________________
dnn_2 (Dense)                   (None, 32)           2080        dnn_1[0][0]
_________________________________________________________________________________
__________________
linear (Dense)                  (None, 10)           720         wide_inputs[0]
[0]
_________________________________________________________________________________
__________________
both (Concatenate)              (None, 42)           0           dnn_2[0][0]
                                                                 linear[0][0]
_________________________________________________________________________________
__________________
weight (Dense)                  (None, 1)            43          both[0][0]
=================================================================================
==================
Total params: 63,227
Trainable params: 63,227
Non-trainable params: 0
_________________________________________________________________________________
__________________
None
```

We can visualize the DNN using the Keras plot_model utility.

In [12]:

```python
tf.keras.utils.plot_model(model, 'wd_model.png', show_shapes=False, rankdir='LR'
```

Out[12]:



Train and evaluate

In [13]:

```python
TRAIN_BATCH_SIZE = 32
NUM_TRAIN_EXAMPLES = 10000 * 5 # training dataset repeats, so it will wrap aroun
NUM_EVALS = 5  # how many times to evaluate
NUM_EVAL_EXAMPLES = 10000 # enough to get a reasonable sample, but not so much t

trainds = load_dataset('train*', TRAIN_BATCH_SIZE, tf.estimator.ModeKeys.TRAIN)
evalds = load_dataset('eval*', 1000, tf.estimator.ModeKeys.EVAL).take(NUM_EVAL_E

steps_per_epoch = NUM_TRAIN_EXAMPLES // (TRAIN_BATCH_SIZE * NUM_EVALS)

history = model.fit(trainds,
                    validation_data=evalds,
                    epochs=NUM_EVALS,
                    steps_per_epoch=steps_per_epoch)
```

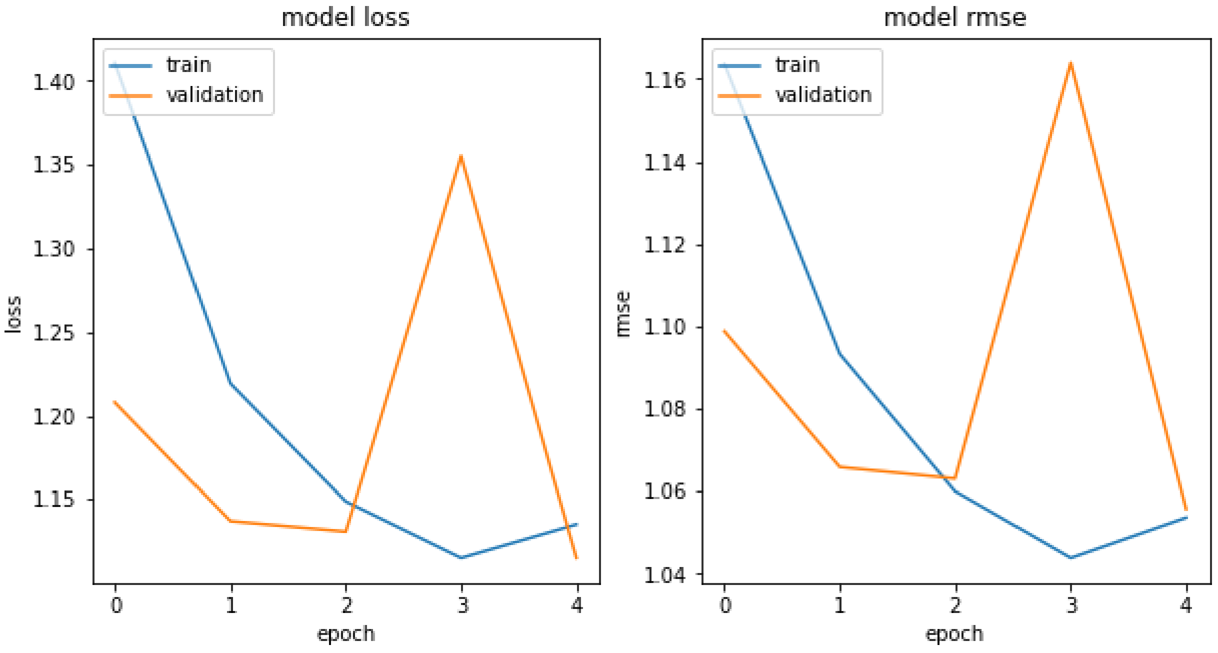
```
Epoch 1/5
312/312 [==============================] - 4s 11ms/step - loss: 1.4109 - rmse:
1.1636 - mse: 1.4109 - val_loss: 1.2079 - val_rmse: 1.0988 - val_mse: 1.2079
```

```
Epoch 2/5
312/312 [==============================] - 2s 8ms/step - loss: 1.2191 - rmse: 1.
0933 - mse: 1.2191 - val_loss: 1.1369 - val_rmse: 1.0659 - val_mse: 1.1369
Epoch 3/5
312/312 [==============================] - 3s 8ms/step - loss: 1.1486 - rmse: 1.
0600 - mse: 1.1486 - val_loss: 1.1307 - val_rmse: 1.0631 - val_mse: 1.1307
Epoch 4/5
312/312 [==============================] - 2s 7ms/step - loss: 1.1150 - rmse: 1.
0439 - mse: 1.1150 - val_loss: 1.3552 - val_rmse: 1.1639 - val_mse: 1.3552
Epoch 5/5
312/312 [==============================] - 2s 6ms/step - loss: 1.1350 - rmse: 1.
0536 - mse: 1.1350 - val_loss: 1.1151 - val_rmse: 1.0557 - val_mse: 1.1151
```

Visualize loss curve

In [14]:

```python
# plot
import matplotlib.pyplot as plt
nrows = 1
ncols = 2
fig = plt.figure(figsize=(10, 5))

for idx, key in enumerate(['loss', 'rmse']):
    ax = fig.add_subplot(nrows, ncols, idx+1)
    plt.plot(history.history[key])
    plt.plot(history.history['val_{}'.format(key)])
    plt.title('model {}'.format(key))
    plt.ylabel(key)
    plt.xlabel('epoch')
    plt.legend(['train', 'validation'], loc='upper left');
```



Save the model

In [15]:

```python
import shutil, os, datetime
OUTPUT_DIR = 'babyweight_trained'
shutil.rmtree(OUTPUT_DIR, ignore_errors=True)
EXPORT_PATH = os.path.join(OUTPUT_DIR, datetime.datetime.now().strftime('%Y%m%d%
tf.saved_model.save(model, EXPORT_PATH) # with default serving function
print("Exported trained model to {}".format(EXPORT_PATH))
```

```
WARNING:tensorflow:From /opt/conda/lib/python3.7/site-packages/tensorflow/pytho
n/training/tracking/tracking.py:111: Model.state_updates (from tensorflow.pytho
n.keras.engine.training) is deprecated and will be removed in a future version.
Instructions for updating:
This property should not be used in TensorFlow 2.0, as updates are applied autom
atically.
WARNING:tensorflow:From /opt/conda/lib/python3.7/site-packages/tensorflow/pytho
n/training/tracking/tracking.py:111: Layer.updates (from tensorflow.python.kera
s.engine.base_layer) is deprecated and will be removed in a future version.
Instructions for updating:
This property should not be used in TensorFlow 2.0, as updates are applied autom
atically.
INFO:tensorflow:Assets written to: babyweight_trained/20210818183030/assets
Exported trained model to babyweight_trained/20210818183030
```

In [16]:

```
!ls $EXPORT_PATH
```

```
assets  saved_model.pb  variables
```

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