Introduction to Keras

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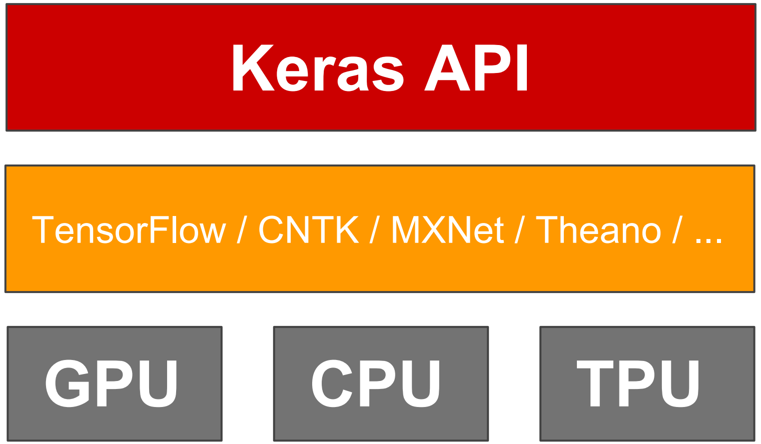
Outline (45 min + questions)

- What's Keras?
  - What's special about it?
  - TensorFlow integration
- How to use Keras
  - 3 API styles
  - An image captioning example
- Distributed, multi-GPU, and TPU training
- Eager execution (a.k.a define-by-run, a.k.a. dynamic graphs)

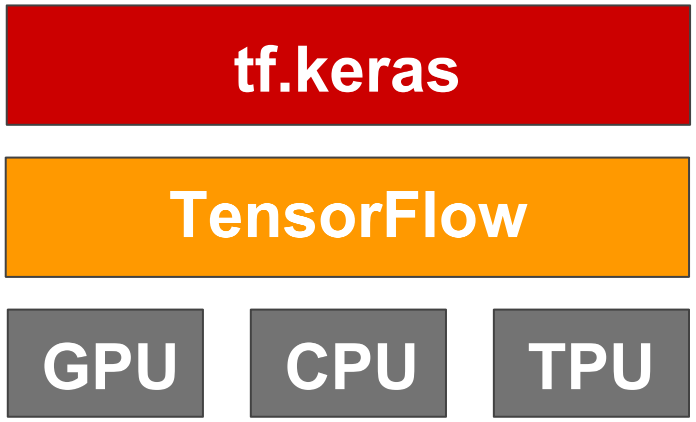
What’s Keras?

Keras: an API for specifying & training differentiable programs



Keras is the official high-level API of TensorFlow

- tensorflow.keras (tf.keras) module
- Part of core TensorFlow since v1.4
- Full Keras API
- Better optimized for TF
- Better integration with TF-specific features
  - Estimator API
  - Eager execution
  - etc.



Who makes Keras? Contributors and backers

633 contributors

Google

Microsoft

NVIDIA

aws

What’s special about Keras?

- A focus on user experience.
- Large adoption in the industry and research community.
- Multi-backend, multi-platform.
- Easy productization of models.

250,000

Keras developers

$> 2x$

Year-on-year growth

Industry traction

NETFLIX UBER Google

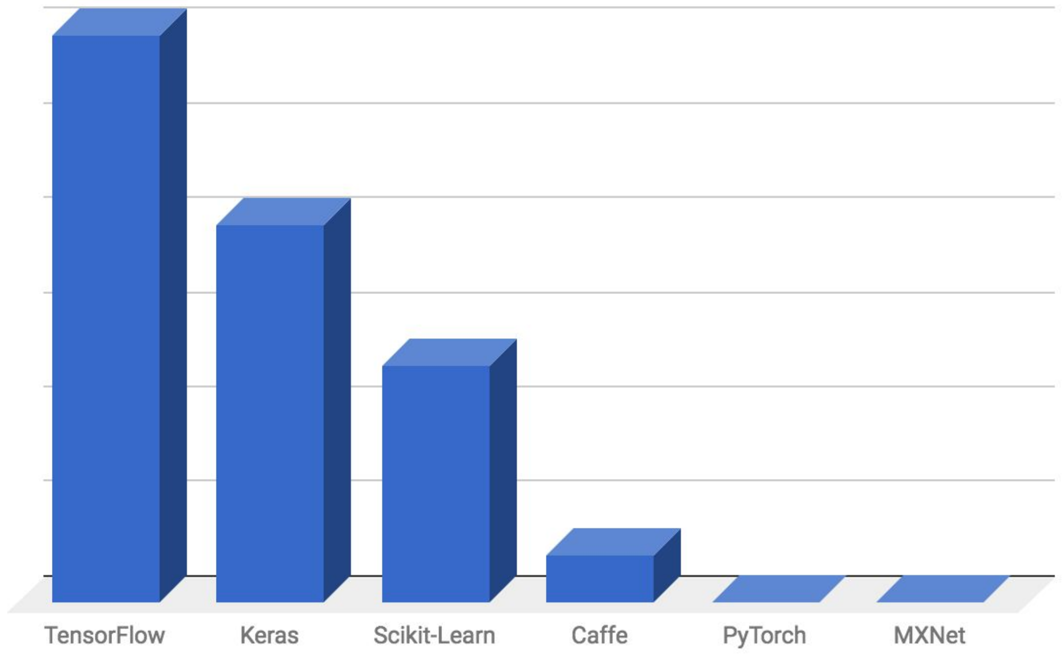
instacart HUAWEI NVIDIA®

Square Expedia® Zocdoc™ yelp

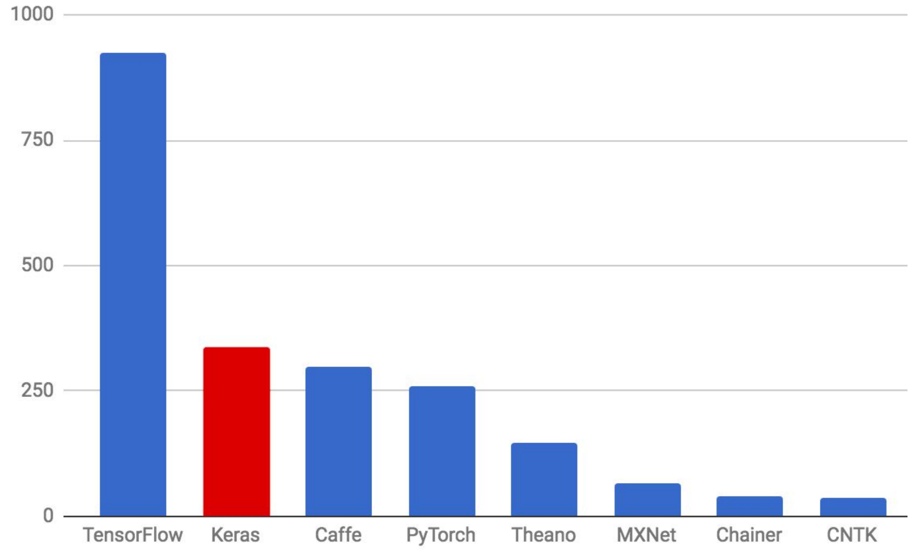
etc...

Startup-land traction

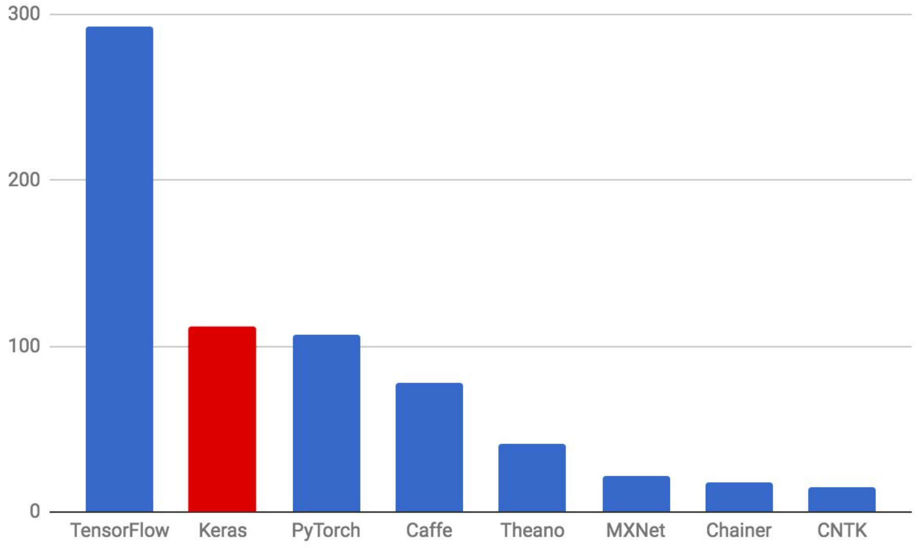
Hacker News jobs board mentions - out of 964 job postings



Research traction



arXiv mentions as of 2018/03/07 (past 3 months)



arXiv mentions as of 2018/03/07 (past 1 month)

The Keras user experience

Keras is an API designed for human beings, not machines. Keras follows best practices for reducing cognitive load: it offers consistent & simple APIs, it minimizes the number of user actions required for common use cases, and it provides clear and actionable feedback upon user error.

This makes Keras easy to learn and easy to use. As a Keras user, you are more productive, allowing you to try more ideas than your competition, faster -- which in turn helps you win machine learning competitions.

This ease of use does not come at the cost of reduced flexibility: because Keras integrates with lower-level deep learning languages (in particular TensorFlow), it enables you to implement anything you could have built in the base language. In particular, as tf.keras, the Keras API integrates seamlessly with your TensorFlow workflows.

Keras is multi-backend, multi-platform

- Develop in Python, R
    - On Unix, Windows, OSX
- Run the same code with…
    - TensorFlow
    - CNTK
    - Theano
    - MXNet
    - PlaidML
    - ??
- CPU, NVIDIA GPU, AMD GPU, TPU…

Largest array of options for productizing models

- TF-Serving
- In-browser, with GPU acceleration (WebKeras, Keras.js, WebDNN...)
- Android (TF, TF Lite), iPhone (native CoreML support)
- Raspberry Pi
- JVM

Go build cool AR apps with Keras + TF + CoreML + ARKit

How to use Keras: An introduction

Three API styles

- The Sequential Model
  - Dead simple
  - Only for single-input, single-output, sequential layer stacks
  - Good for 70+% of use cases
- The functional API
  - Like playing with Lego bricks
  - Multi-input, multi-output, arbitrary static graph topologies
  - Good for 95% of use cases
- Model subclassing
  - Maximum flexibility
  - Larger potential error surface

The Sequential API

```python
import keras
from keras import layers

model = keras.Sequential()
model.add(layers.Dense(20, activation='relu', input_shape=(10,)))
model.add(layers.Dense(20, activation='relu'))
model.add(layers.Dense(10, activation='softmax'))

model.fit(x, y, epochs=10, batch_size=32)
```

The functional API

```
import keras
from keras import layers

inputs = keras.Input(shape=(10,))
x = layers.Dense(20, activation='relu')(x)
x = layers.Dense(20, activation='relu')(x)
outputs = layers.Dense(10, activation='softmax')(x)

model = keras.Model(inputs, outputs)
model.fit(x, y, epochs=10, batch_size=32)
```

Model subclassing

```
import keras
from keras import layers

class MyModel(keras.Model):

    def __init__(self):
        super(MyModel, self).__init__()
        self.dense1 = layers.Dense(20, activation='relu')
        self.dense2 = layers.Dense(20, activation='relu')
        self.dense3 = layers.Dense(10, activation='softmax')

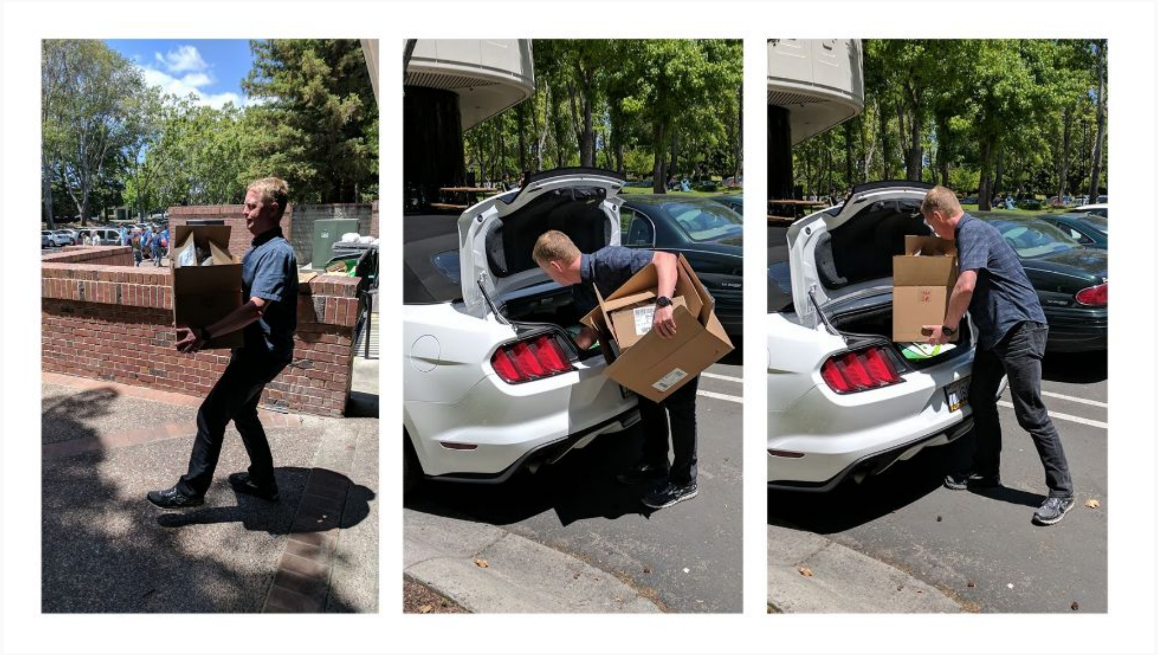
    def call(self, inputs):
        x = self.dense1(x)
        x = self.dense2(x)
        return self.dense3(x)

model = MyModel()
model.fit(x, y, epochs=10, batch_size=32)
```

Remember: use the right tool (API) for the job!

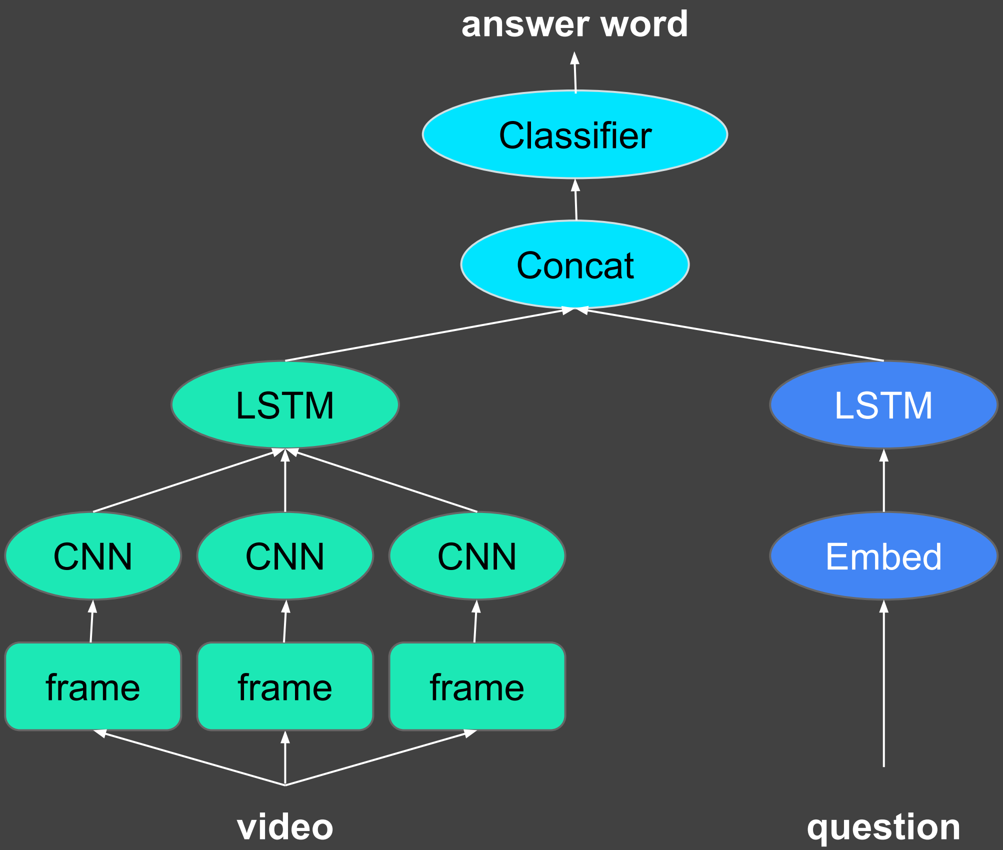
Example: building a video captioning model

Toy video-QA problem

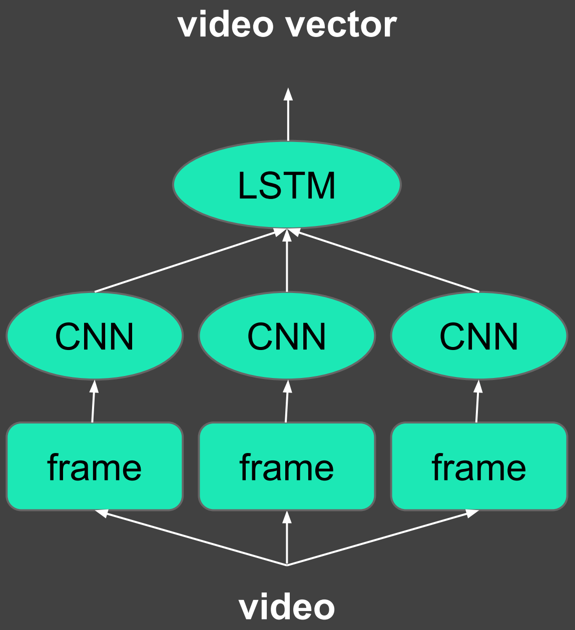


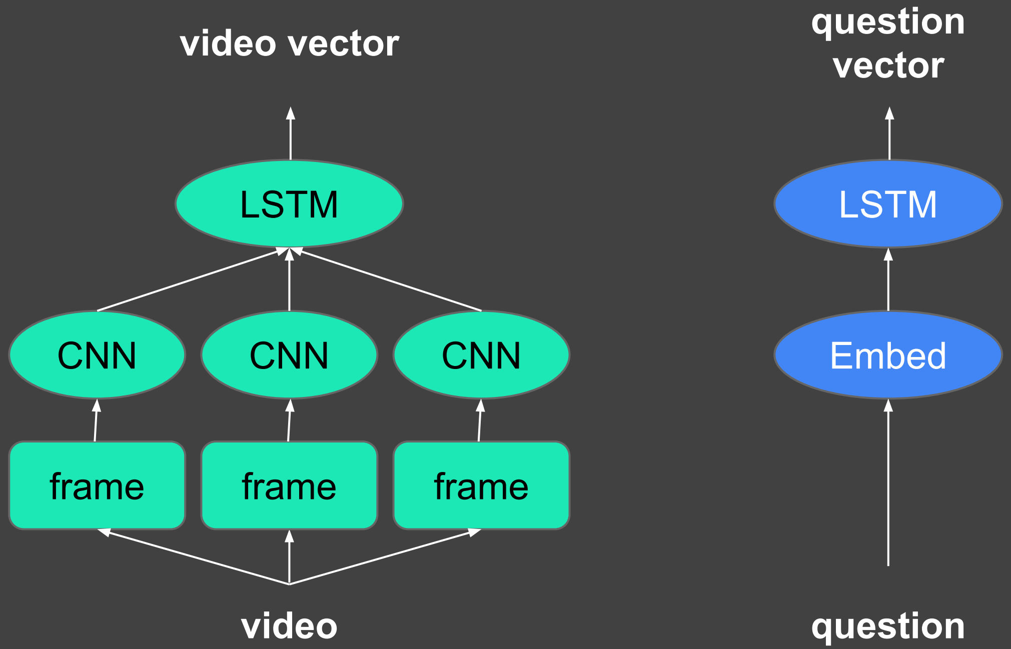
> ***"What is the man doing?"***
> packing

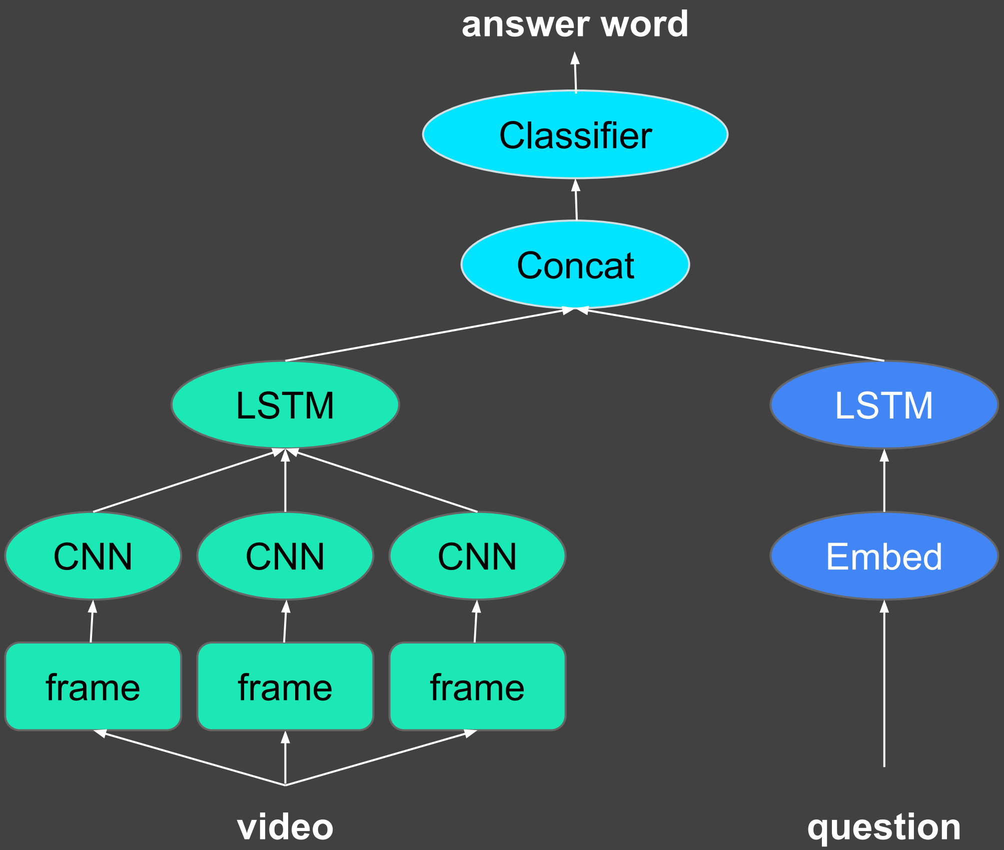
> ***"What color is his shirt?"***
> blue


answer word
Classifier
Concat
LSTM
LSTM
CNN
CNN
CNN
Embed
frame
frame
frame
video
question

from frames to a vector




video vector
LSTM
CNN
CNN
CNN
frame
frame
frame
video
question vector
LSTM
Embed
question


answer word
Classifier
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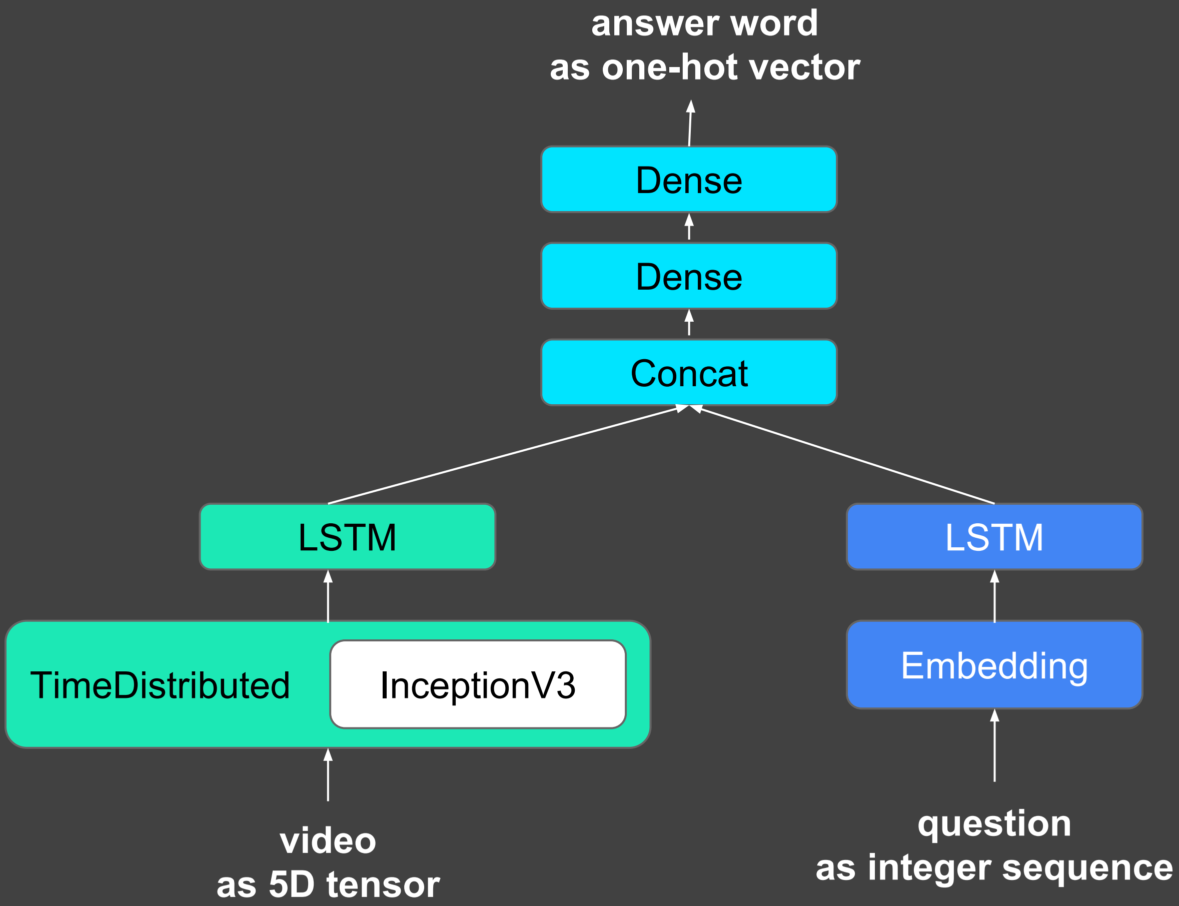
answer word
as one-hot vector
Dense
Dense
Concat
LSTM
LSTM
TimeDistributed
InceptionV3
Embedding
video
as 5D tensor
question
as integer sequence

Turning frames into a vector, with pre-trained representations

```
import keras
from keras import layers
from keras.applications import InceptionV3

video = keras.Input(shape=(None, 150, 150, 3), name='video')
cnn = InceptionV3(weights='imagenet',
                  include_top=False,
                  pooling='avg')
cnn.trainable = False
frame_features = layers.TimeDistributed(cnn)(video)
video_vector = layers.LSTM(256)(frame_features)
```

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video_vector = layers.LSTM(256)(frame_features)
```

Turning a sequence of words into a vector

```
question = keras.Input(shape=(None,), dtype='int32', name='question')
embedded_words = layers.Embedding(input_voc_size, 256)(question)
question_vector = layers.LSTM(128)(embedded_words)
```

Predicting an answer word

```
x = layers.concatenate([video_vector, question_vector])
x = layers.Dense(128, activation=tf.nn.relu)(x)
predictions = layers.Dense(output_voc_size,
                           activation='softmax',
                           name='predictions')(x)
```

Setting up the training configuration

```
model = keras.models.Model([video, question], predictions)
model.compile(optimizer=tf.AdamOptimizer(),
              loss=keras.losses.categorical_crossentropy)

model.fit_generator(data_generator,
                    steps_per_epoch=1000,
                    epochs=100)
```

Distributed, multi-GPU, & TPU training

Distributed

- Uber’s Horovod
- Estimator API (TF built-in option)
- Dist-Keras (Spark)
    - Also Elephas (Spark)

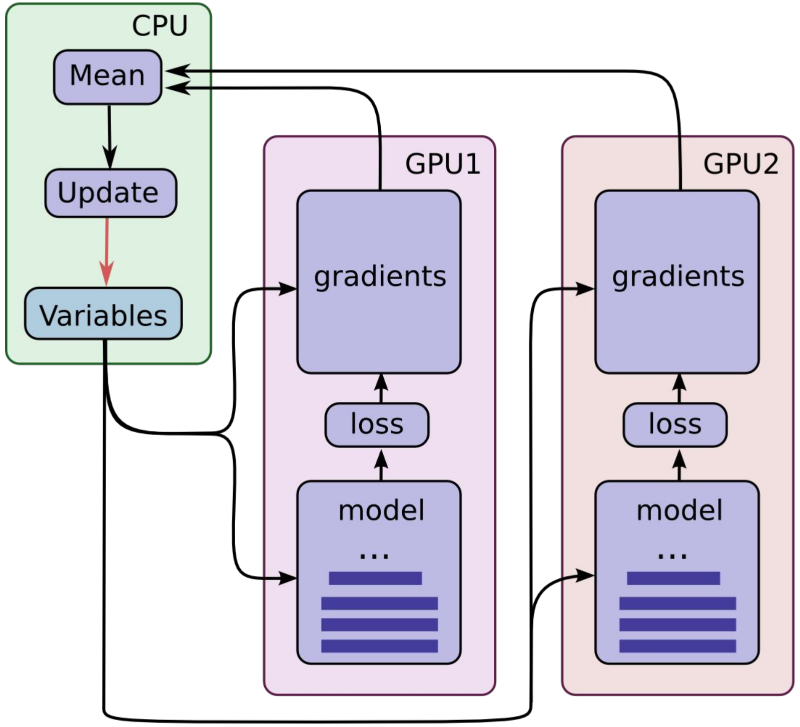
Built-in multi-GPU support

```python
import tensorflow as tf
from keras.applications import Xception
from keras.utils import multi_gpu_model

# Instantiate the base model
# (here, we do it on CPU, which is optional).
with tf.device('/cpu:0'):
    model = Xception(weights=None,
                     input_shape=(height, width, 3),
                     classes=num_classes)

# Replicates the model on 8 GPUs.
# This assumes that your machine has 8 available GPUs.
parallel_model = multi_gpu_model(model, gpus=8)
parallel_model.compile(loss='categorical_crossentropy',
                       optimizer='rmsprop')

# This `fit` call will be distributed on 8 GPUs.
# Since the batch size is 256, each GPU will process 32 samples.
parallel_model.fit(x, y, epochs=20, batch_size=256)
```



TPU support

Training + inference

Via Estimator API

Eager execution

Understanding deferred (symbolic) vs. eager (imperative)

Deferred: you use Python to build a computation graph that gets executed later

Eager: the Python runtime is the execution runtime (like Numpy)

In short:

- Symbolic tensors **don't have a value** in your Python code (yet)
- Eager tensors **have a value** in your Python code
- With eager execution, you can use value-dependent dynamic topologies (tree-RNNs)

The Keras functional API and Sequential API work with eager execution

```python
import keras
from keras import layers
import tensorflow.contrib.eager as tfe

tfe.enable_eager_execution()

inputs = keras.Input(shape=(10,))
x = layers.Dense(20, activation='relu')(x)
x = layers.Dense(20, activation='relu')(x)
outputs = layers.Dense(10, activation='softmax')(x)

model = keras.Model(inputs, outputs)

preds = model(x)  # Works on *value arrays*!
model.fit(x, y, epochs=10, batch_size=32)  # The Model API works too.
```

Eager execution allows you to write imperative custom layers

```
class DynamicLayer(tf.keras.Layer):

  ...

  def call(self, x):
    print(x)  # debug!
    if tf.reduce_sum(x) == 0:
      # dynamic if!
      return x

    for t in x.shape[1]:
      # dynamically iterate over time axis!
      ...

    return outputs
```

Maximum flexibility: imperative Model subclassing

```
class MyRNN(keras.Model):

    def __init__(self, units=10):
        super(MyRNN, self).__init__(name='my_rnn')
        self.units = units
        self.dense_1 = keras.layers.Dense(units, activation='relu')
        self.dense_2 = keras.layers.Dense(units, activation='relu')

    def call(self, inputs):
        outputs = []
        state = tf.zeros(shape=(inputs.shape[0], self.units))
        for t in range(inputs.shape[1]):
            x = inputs[:, t, :]
            h = self.dense_1(x)
            y = h + self.dense_2(state)
            state = y
            outputs.append(y)
        return tf.concatenate(outputs, axis=1)
```

That’s it.
Thank you!