Einführung in

Sören Wegener

HackWat! flipdot Kassel

02. Juni 2018

Was ist TensorFlow?

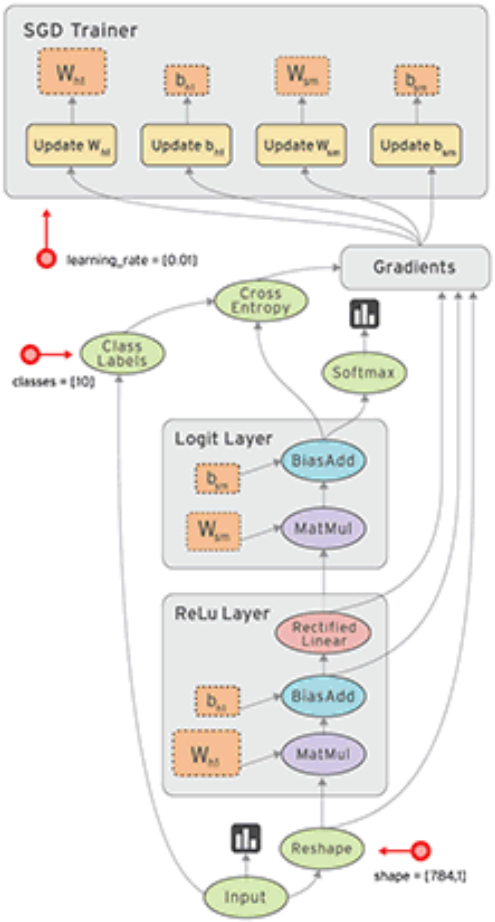
- Machine Learning Library für Python
- Entstanden aus Googles *DistBelief*
- Im Einsatz bei z.B. Google Suche[1], Google Mail[1], Snapchat[2]

[1] https://tensorflow.org/about/uses

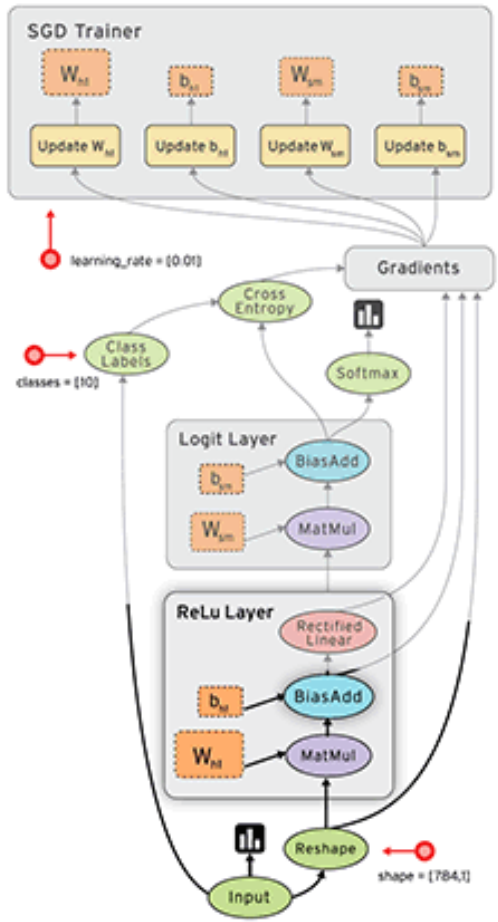
[2] https://www.tensorflow.org/

Python?
Das ist doch viel zu langsam!

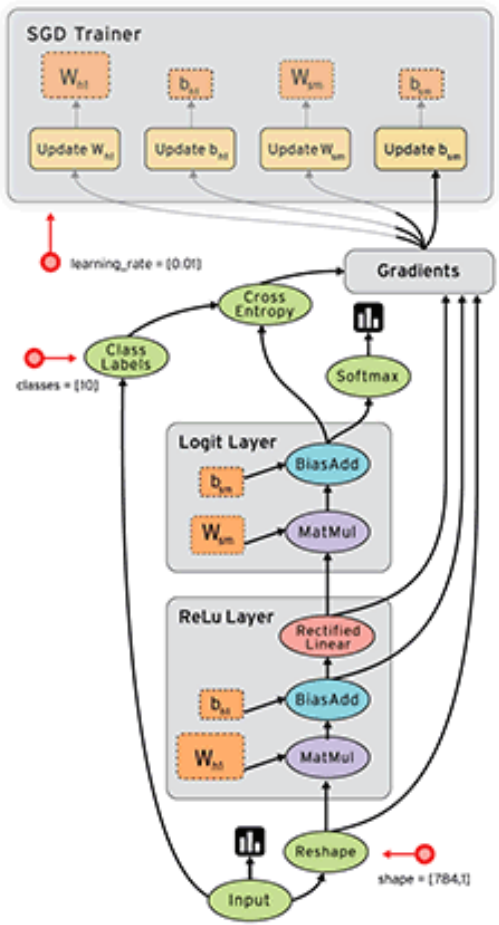
Computation Graph



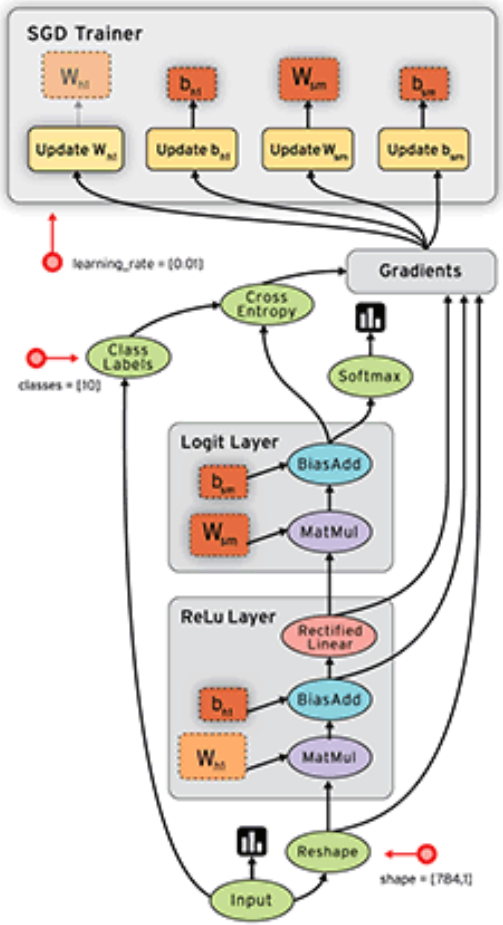
Computation Graph



Computation Graph



Computation Graph



Zwei APIs

TensorFlow Core

- Umsetzung von Modellen

Higher Level APIs

- Abstrakte Probleme lösen

Minimales Beispiel

```
1  import tensorflow as tf
2
3  a = tf.constant(3) # Tensor, rank 0
4  b = tf.constant(14, dtype='int32')
```

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3  a = tf.constant(3) # Tensor, rank 0
4  b = tf.constant(14, dtype='int32')
5  c = tf.multiply(a, b, name='awesome_multiplication')
6  # oder: c = a * b
```

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5  c = tf.multiply(a, b, name='awesome_multiplication')
6  # oder: c = a * b
7  sess = tf.Session()
8  result = sess.run(c)
```

TensorBoard

Logfiles schreiben:

```
tf.summary.FileWriter('./logdir/slide6', sess.graph)
```

TensorBoard

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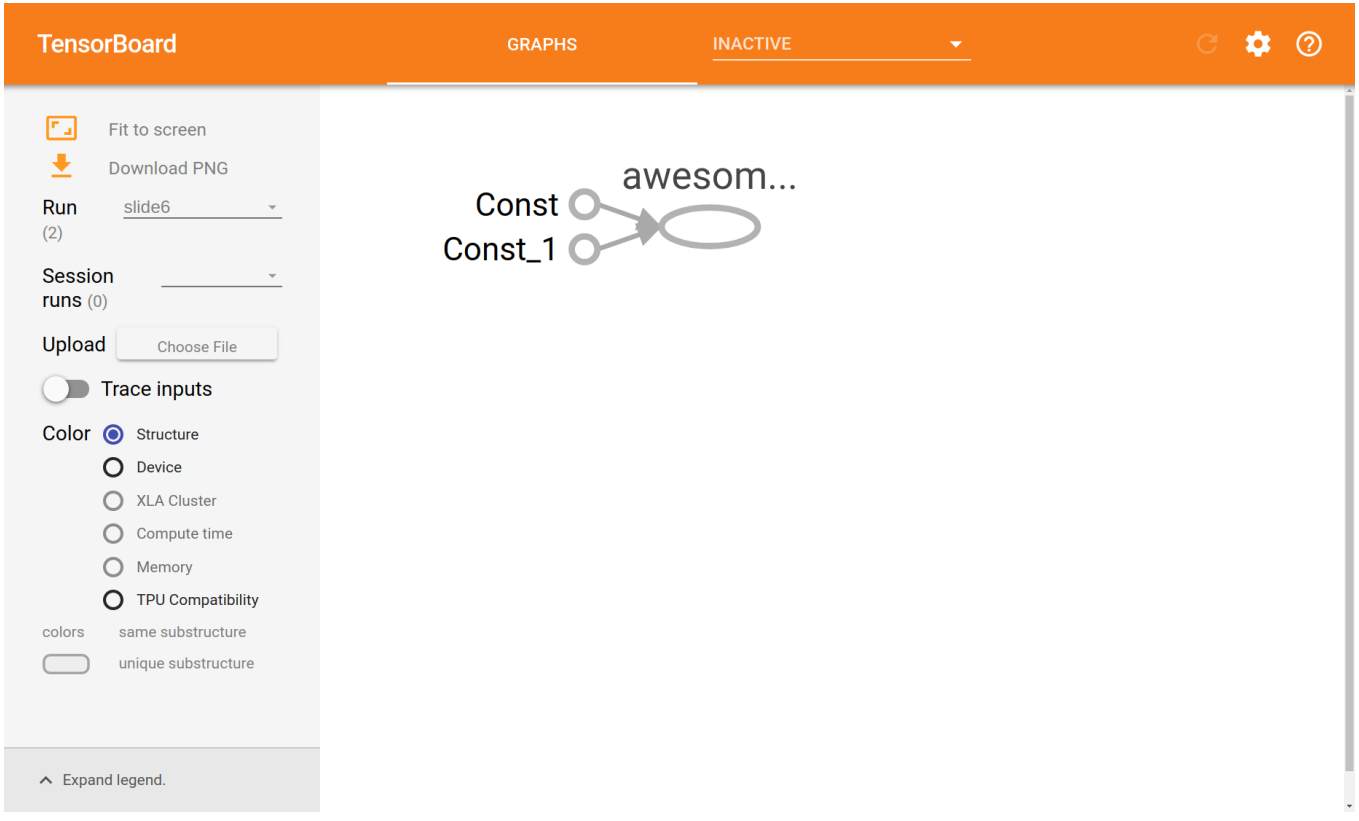
```
tf.summary.FileWriter('./logdir/slide6', sess.graph)
```

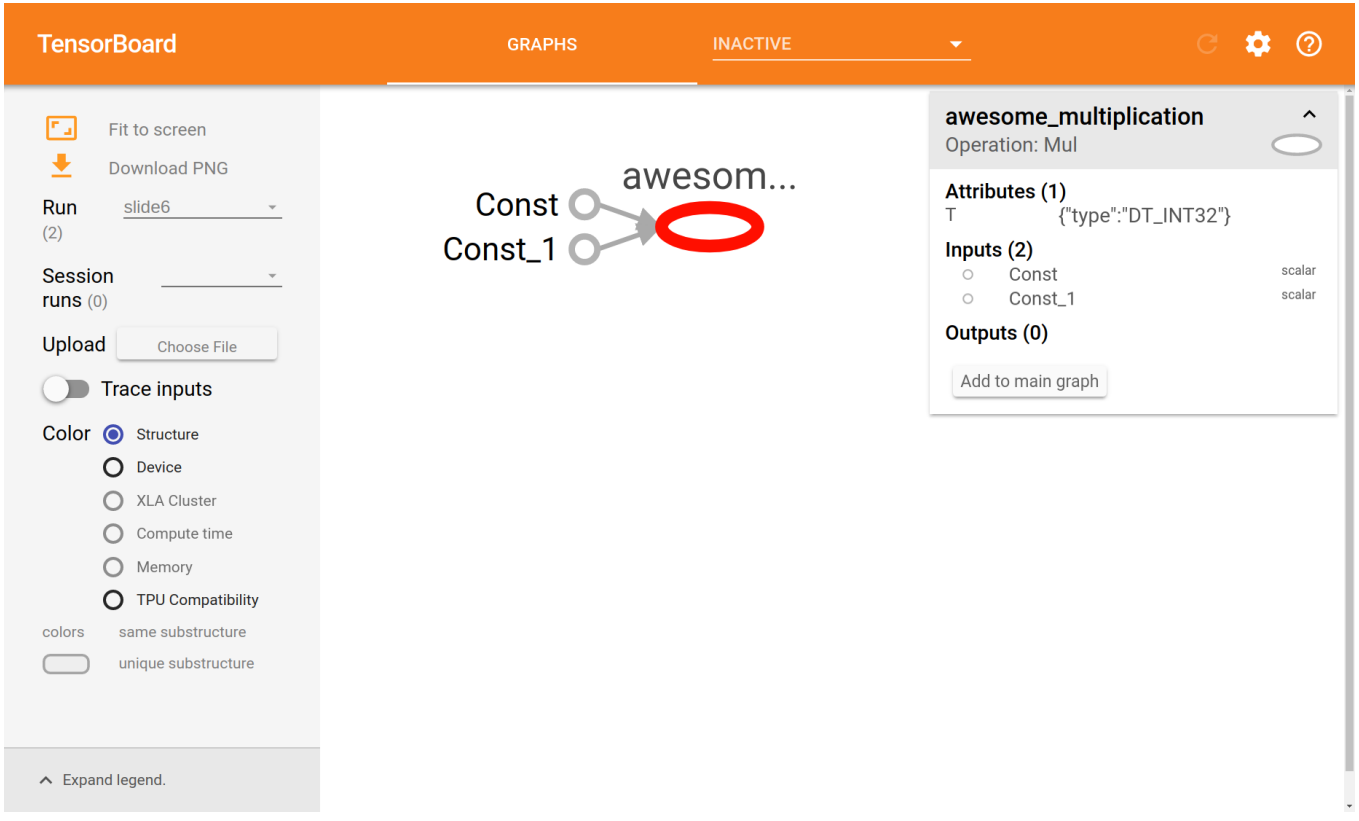
In der Shell starten:

```
$ tensorboard --logdir=logdir
```

TensorBoard



TensorBoard



Placeholder

```
1  a = tf.placeholder(dtype='int32')
2  b = tf.constant(10)
```

Placeholder

```
1  a = tf.placeholder(dtype='int32')
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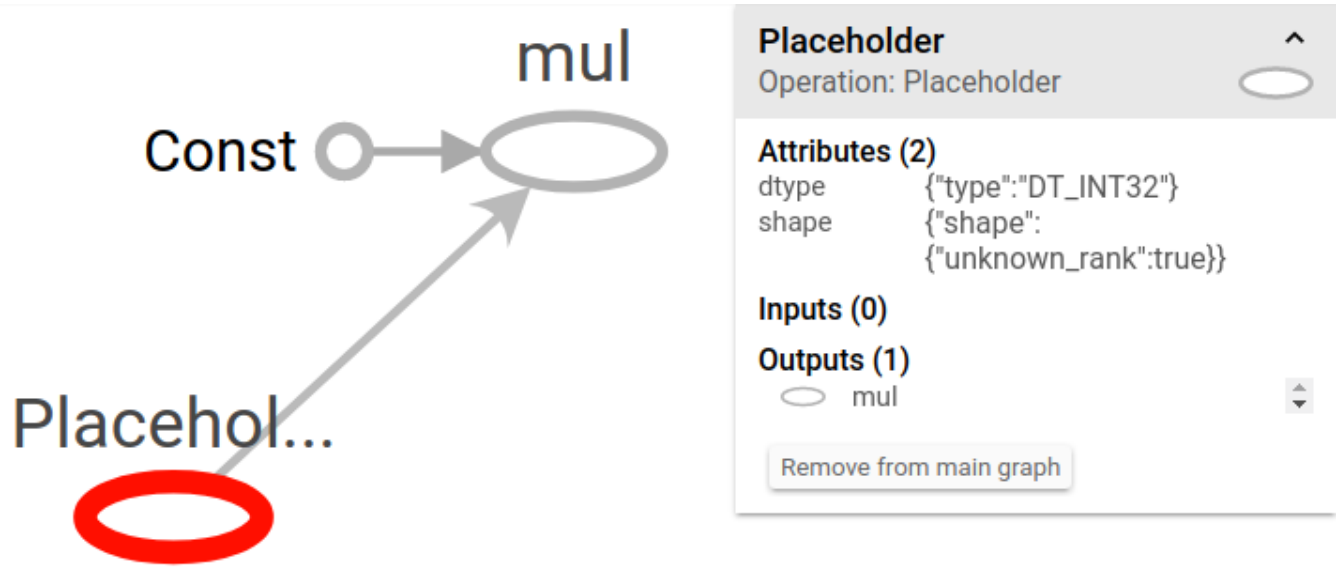
```

Placeholder

```
1  a = tf.placeholder(dtype='int32')
2  b = tf.constant(10)
3  c = a * b
4  sess = tf.Session()
5  result = sess.run(c, feed_dict={a: 30})
```

Placeholder



Variablen

```
1  v = tf.get_variable('my_variable', shape=[2, 3])
2  b = tf.constant(10, dtype='float32')
```

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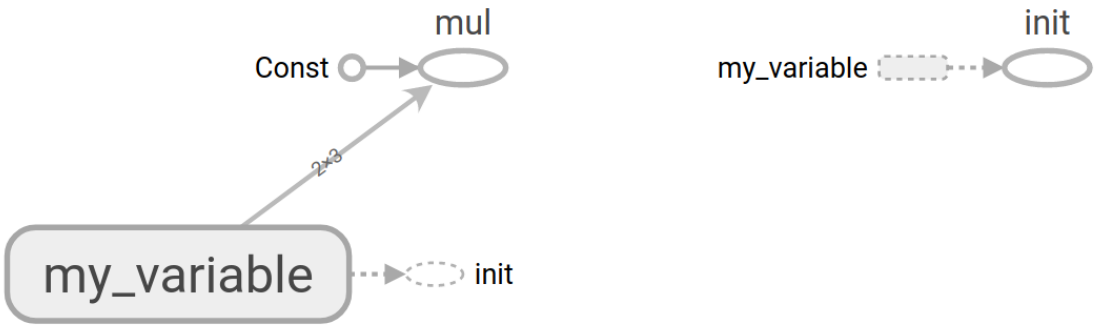
5  sess.run(tf.global_variables_initializer())
6  result = sess.run(c)
```

Variablen

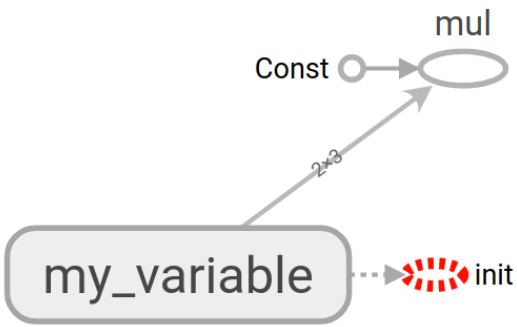
```
1  v = tf.get_variable('my_variable', shape=[2, 3])
2  b = tf.constant(10, dtype='float32')
3  c = v * b
4  sess = tf.Session()
5  sess.run(tf.global_variables_initializer())
6  result = sess.run(c)
7  print(result)
```

```
[[-7.83156967  5.84567547 -5.6848073 ]
 [ 2.27666855 -8.07361794 -4.07426929]]
```

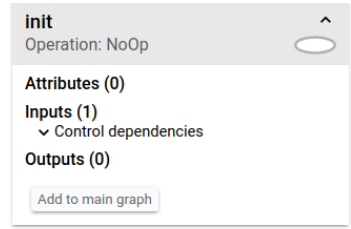
Variablen



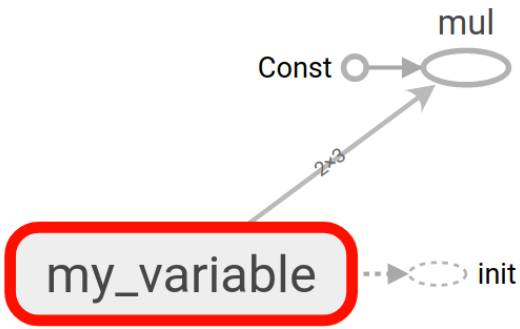
Variablen


mul
Const
2×3
my_variable
init


init
my_variable


init
Operation: NoOp
Attributes (0)
Inputs (1)
Control dependencies
Outputs (0)
Add to main graph

Variablen


mul
Const
2×3
my_variable
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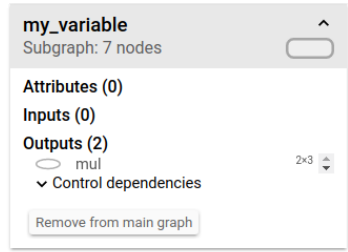
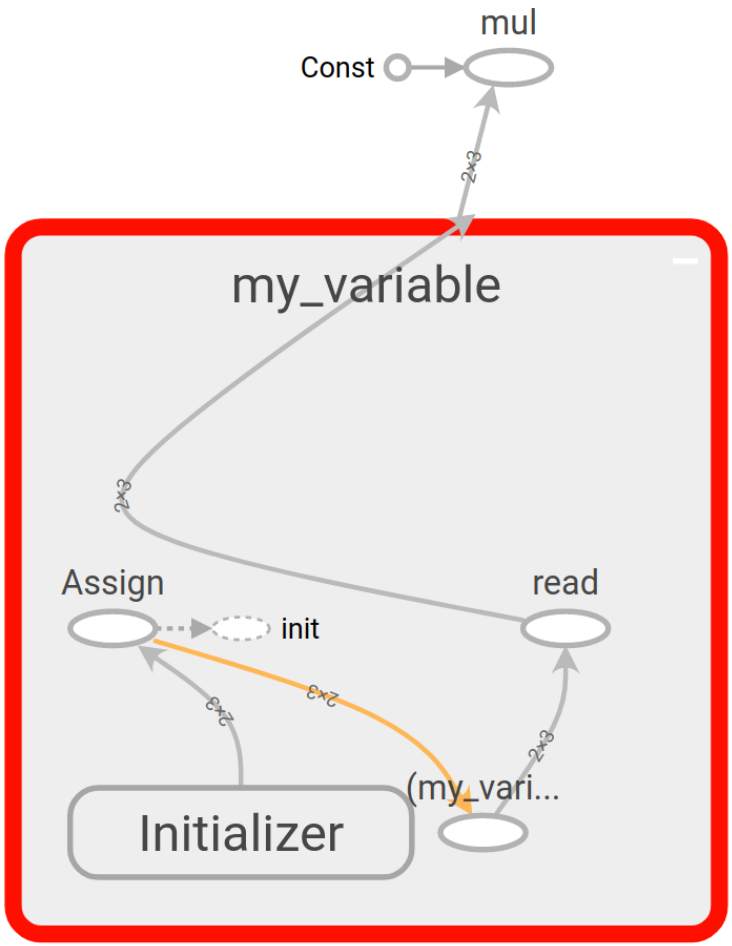
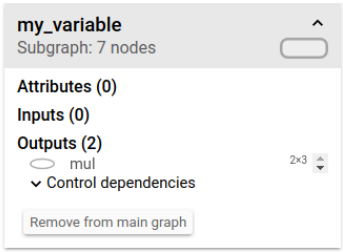

my_variable
Subgraph: 7 nodes
Attributes (0)
Inputs (0)
Outputs (2)
mul
2×3
Control dependencies
Remove from main graph

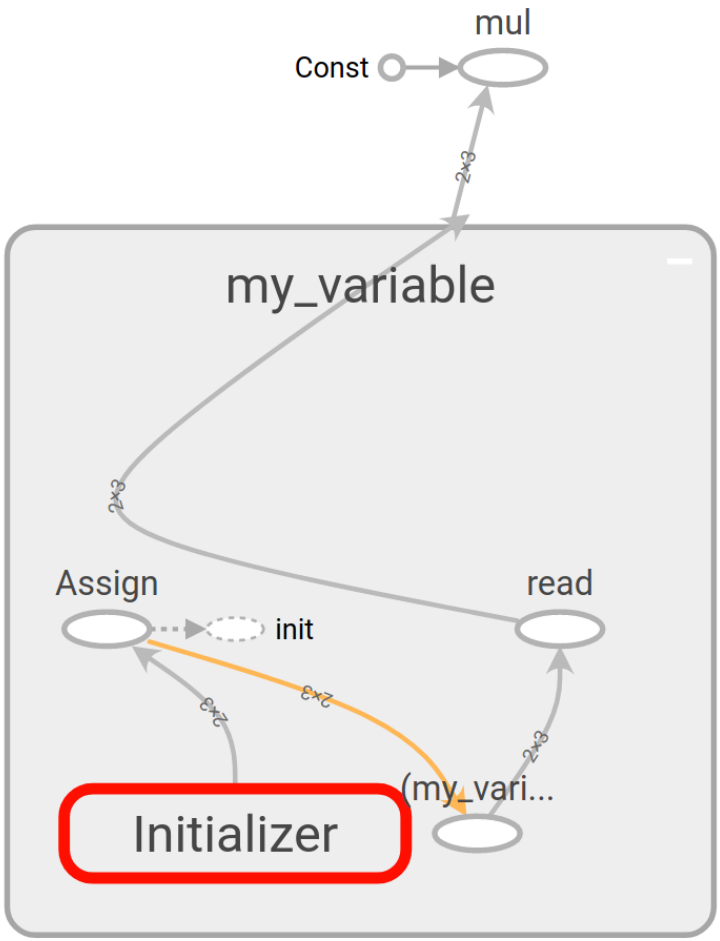
Variablen


mul
Const
2×3
my_variable
2×3
Assign
read
init
2×3
2×3
2×3
(my_vari...
Initializer

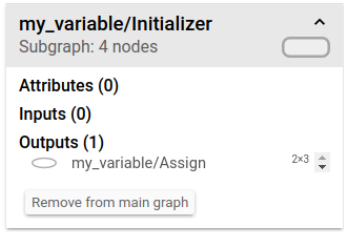

init
my_variable


my_variable
Subgraph: 7 nodes
Attributes (0)
Inputs (0)
Outputs (2)
mul
2×3
Control dependencies
Remove from main graph

Variablen


mul
Const
2×3
my_variable
2×3
Assign
read
init
2×3
2×3
2×3
(my_vari...
Initializer


init
my_variable


my_variable/Initializer
Subgraph: 4 nodes
Attributes (0)
Inputs (0)
Outputs (1)
my_variable/Assign
2×3
Remove from main graph

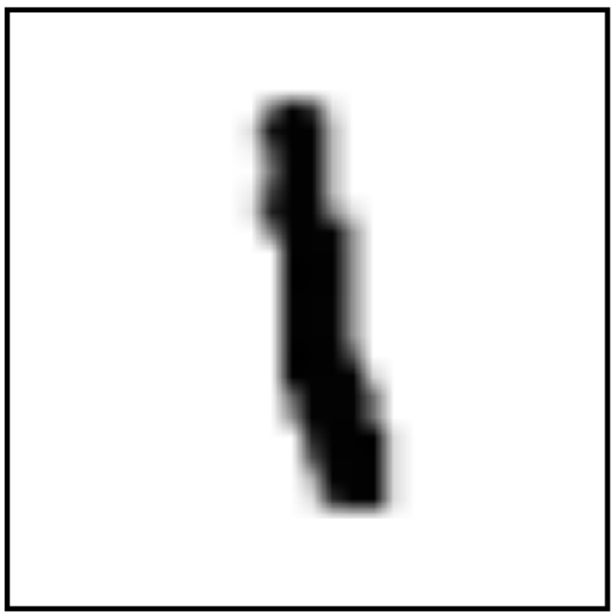
TensorFlow am Beispiel von MNIST

MNIST?

- Handgeschriebene Ziffern, 28x28 Pixel

Tutorial und Bildmaterial von `https://www.tensorflow.org/get_started/mnist/beginners`

Darstellung als 784-elementiges Array

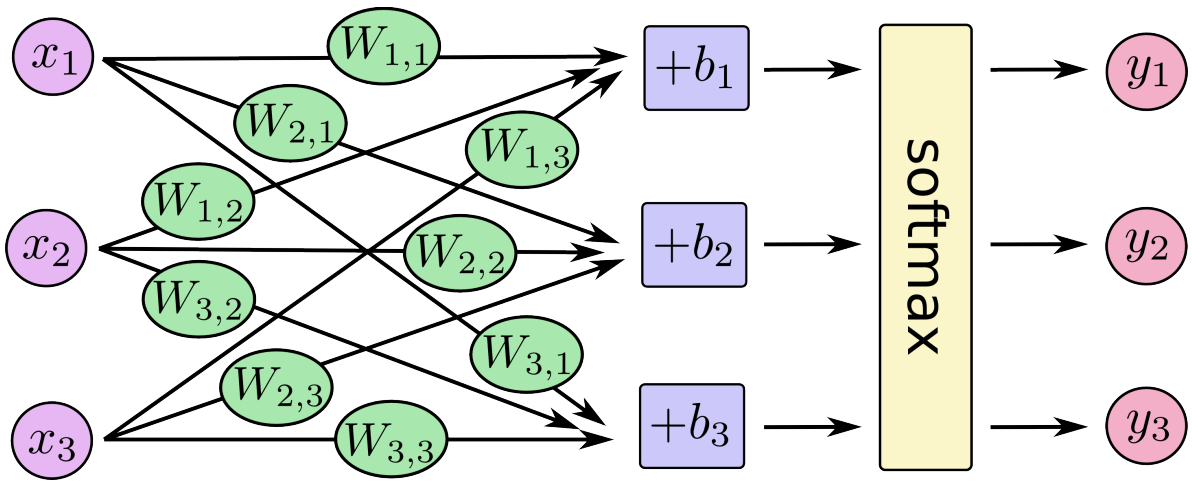


≈

$$
\begin{bmatrix}
0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 \\
0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 \\
0 & 0 & 0 & 0 & 0 & 0 & .6 & .8 & 0 & 0 & 0 & 0 & 0 & 0 \\
0 & 0 & 0 & 0 & 0 & 0 & .7 & 1 & 0 & 0 & 0 & 0 & 0 & 0 \\
0 & 0 & 0 & 0 & 0 & 0 & .7 & 1 & 0 & 0 & 0 & 0 & 0 & 0 \\
0 & 0 & 0 & 0 & 0 & 0 & .5 & 1 & .4 & 0 & 0 & 0 & 0 & 0 \\
0 & 0 & 0 & 0 & 0 & 0 & 0 & 1 & .4 & 0 & 0 & 0 & 0 & 0 \\
0 & 0 & 0 & 0 & 0 & 0 & 0 & 1 & .4 & 0 & 0 & 0 & 0 & 0 \\
0 & 0 & 0 & 0 & 0 & 0 & 0 & 1 & .7 & 0 & 0 & 0 & 0 & 0 \\
0 & 0 & 0 & 0 & 0 & 0 & 0 & 1 & 1 & 0 & 0 & 0 & 0 & 0 \\
0 & 0 & 0 & 0 & 0 & 0 & 0 & .9 & 1 & .1 & 0 & 0 & 0 & 0 \\
0 & 0 & 0 & 0 & 0 & 0 & 0 & .3 & 1 & .1 & 0 & 0 & 0 & 0 \\
0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 \\
0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0
\end{bmatrix}
$$

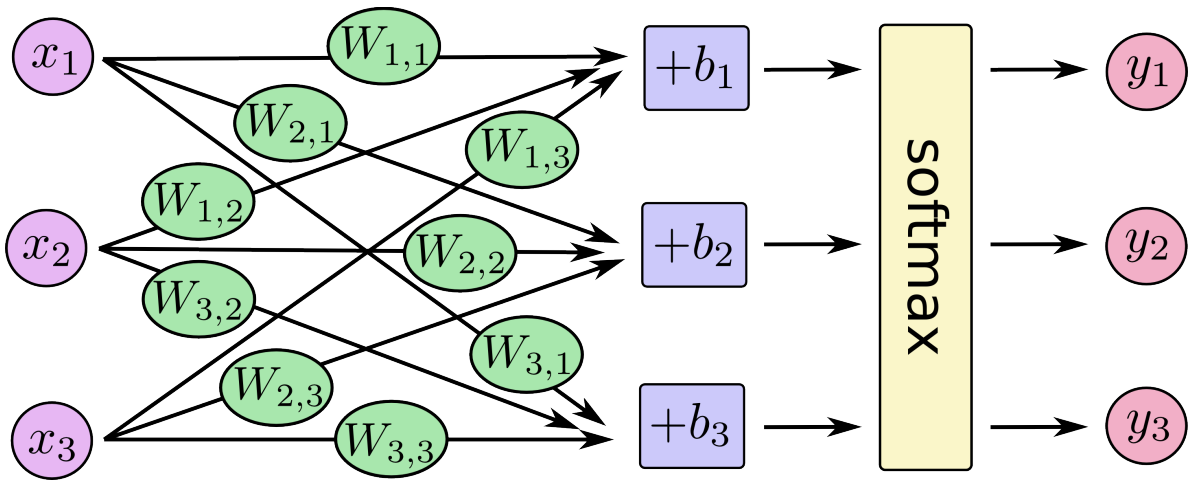
Das Modell

$x_1 \ldots x_{784}, b_1 \ldots b_{10}, y_1 \ldots y_{10}$



Das Modell

$x_1 \ldots x_{784}, b_1 \ldots b_{10}, y_1 \ldots y_{10}$



$$\begin{bmatrix} y_1 \\ y_2 \\ y_3 \end{bmatrix} = \text{softmax}\left(\begin{bmatrix} W_{1,1} & W_{1,2} & W_{1,3} \\ W_{2,1} & W_{2,2} & W_{2,3} \\ W_{3,1} & W_{3,2} & W_{3,3} \end{bmatrix} \cdot \begin{bmatrix} x_1 \\ x_2 \\ x_3 \end{bmatrix} + \begin{bmatrix} b_1 \\ b_2 \\ b_3 \end{bmatrix} \right)$$

Das Modell

$$\begin{bmatrix} y_1 \\ y_2 \\ y_3 \end{bmatrix} = \text{softmax}\left(\begin{bmatrix} W_{1,1} & W_{1,2} & W_{1,3} \\ W_{2,1} & W_{2,2} & W_{2,3} \\ W_{3,1} & W_{3,2} & W_{3,3} \end{bmatrix} \cdot \begin{bmatrix} x_1 \\ x_2 \\ x_3 \end{bmatrix} + \begin{bmatrix} b_1 \\ b_2 \\ b_3 \end{bmatrix} \right)$$

```
1  x = tf.placeholder(tf.float32, [None, 784], name='images')
```

Das Modell

$$\begin{bmatrix} y_1 \\ y_2 \\ y_3 \end{bmatrix} = \text{softmax}\left(\begin{bmatrix} W_{1,1} & W_{1,2} & W_{1,3} \\ W_{2,1} & W_{2,2} & W_{2,3} \\ W_{3,1} & W_{3,2} & W_{3,3} \end{bmatrix} \cdot \begin{bmatrix} x_1 \\ x_2 \\ x_3 \end{bmatrix} + \begin{bmatrix} b_1 \\ b_2 \\ b_3 \end{bmatrix} \right)$$

```
1  x = tf.placeholder(tf.float32, [None, 784], name='images')
2  y_ = tf.placeholder(tf.float32, [None, 10], name='labels')
```

Das Modell

$$\begin{bmatrix} y_1 \\ y_2 \\ y_3 \end{bmatrix} = \text{softmax}\left(\begin{bmatrix} W_{1,1} & W_{1,2} & W_{1,3} \\ W_{2,1} & W_{2,2} & W_{2,3} \\ W_{3,1} & W_{3,2} & W_{3,3} \end{bmatrix} \cdot \begin{bmatrix} x_1 \\ x_2 \\ x_3 \end{bmatrix} + \begin{bmatrix} b_1 \\ b_2 \\ b_3 \end{bmatrix} \right)$$

```
1  x = tf.placeholder(tf.float32, [None, 784], name='images')
2  y_ = tf.placeholder(tf.float32, [None, 10], name='labels')
3  W = tf.Variable(tf.zeros([784, 10]), name='weights')
4  b = tf.Variable(tf.zeros([10]), name='bias')
```

Das Modell

$$\begin{bmatrix} y_1 \\ y_2 \\ y_3 \end{bmatrix} = \text{softmax}\left(\begin{bmatrix} W_{1,1} & W_{1,2} & W_{1,3} \\ W_{2,1} & W_{2,2} & W_{2,3} \\ W_{3,1} & W_{3,2} & W_{3,3} \end{bmatrix} \cdot \begin{bmatrix} x_1 \\ x_2 \\ x_3 \end{bmatrix} + \begin{bmatrix} b_1 \\ b_2 \\ b_3 \end{bmatrix} \right)$$

```
1  x = tf.placeholder(tf.float32, [None, 784], name='images')
2  y_ = tf.placeholder(tf.float32, [None, 10], name='labels')
3  W = tf.Variable(tf.zeros([784, 10]), name='weights')
4  b = tf.Variable(tf.zeros([10]), name='bias')
5  y = tf.matmul(x, W) + b
```

Der Fehler

- Kreuzentropie als Fehlermaß (*loss-Funktion*)

$$\begin{bmatrix} 0 \\ 0 \\ 0 \\ 0 \\ 0 \\ 0 \\ 0 \\ 0 \\ 0 \\ 1 \end{bmatrix} \neq \begin{bmatrix} 0.2 \\ 0.02 \\ 0.01 \\ 0.01 \\ 0.01 \\ 0.03 \\ 0.01 \\ 0.01 \\ 0.2 \\ 0.5 \end{bmatrix}$$

Der Fehler

```
5  y = tf.matmul(x, W) + b
6
7  cross_entropy = tf.reduce_mean(
8      tf.nn.softmax_cross_entropy_with_logits(labels=y_,
9                                              logits=y)
10 )
```

Der Fehler

```
5  y = tf.matmul(x, W) + b
6
7  cross_entropy = tf.reduce_mean(
8      tf.nn.softmax_cross_entropy_with_logits(labels=y_,
9                                              logits=y)
10 )
11 optimizer = tf.train.GradientDescentOptimizer(
12     0.5
13 ).minimize(cross_entropy)
```

Trainieren...

```
14  sess = tf.Session()
15  sess.run(tf.global_variables_initializer())
```

Trainieren...

```
14  sess = tf.Session()
15  sess.run(tf.global_variables_initializer())
16  for i in range(1000):
17      batch_xs, batch_ys = mnist.train.next_batch(100)
```

Trainieren...

```
14  sess = tf.Session()
15  sess.run(tf.global_variables_initializer())
16  for i in range(1000):
17      batch_xs, batch_ys = mnist.train.next_batch(100)
18      sess.run(optimizer, feed_dict={
19          x: batch_xs,
20          y_: batch_ys
21      })
```

. . . und testen

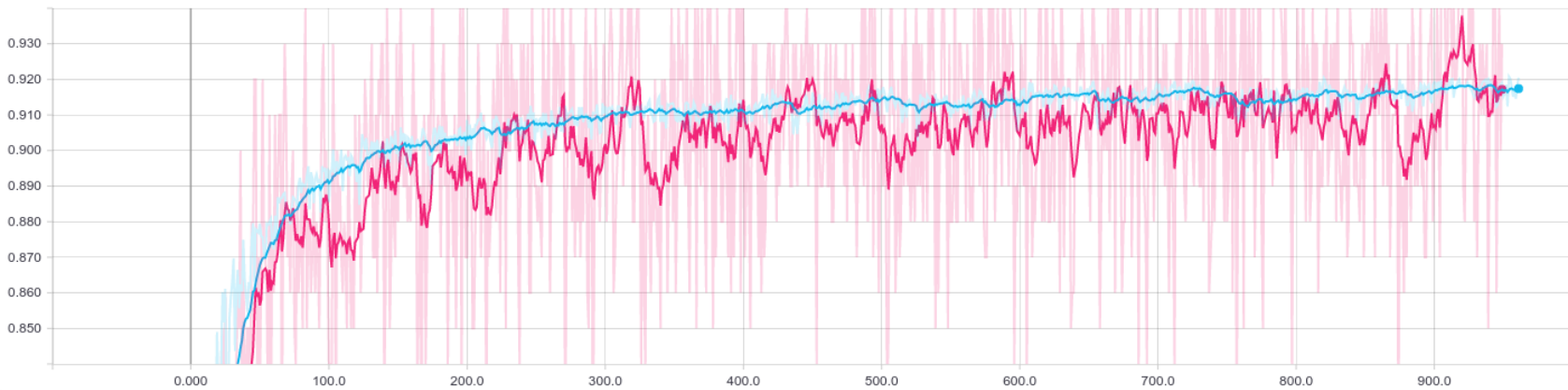
```
22  correct_prediction = tf.equal(tf.argmax(y, 1),
23                                tf.argmax(y_, 1))
24  accuracy = tf.reduce_mean(tf.cast(correct_prediction,
25                                    tf.float32))
```

. . . und testen

```
22  correct_prediction = tf.equal(tf.argmax(y, 1),
23                                tf.argmax(y_, 1))
24  accuracy = tf.reduce_mean(tf.cast(correct_prediction,
25                                    tf.float32))
26  sess.run(accuracy, feed_dict={
27      x: mnist.test.images,
28      y_: mnist.test.labels
29  })
```

Trainingsverlauf

- 92% Accuracy
- $>$ 99% mit anderen Modellen möglich



Boah ey, Mathematik

Immer Mathematik, überall Mathematik, ey!

Bilderkennung

```
1  import tensorflow as tf
2  import numpy as np
3  from pprint import pprint
4
5  image = tf.contrib.keras.preprocessing.image
6  vgg16 = tf.contrib.keras.applications.vgg16
7  model = vgg16.VGG16()
```

Bilderkennung

```
1  import tensorflow as tf
2  import numpy as np
3  from pprint import pprint
4
5  image = tf.contrib.keras.preprocessing.image
6  vgg16 = tf.contrib.keras.applications.vgg16
7  model = vgg16.VGG16()
8  img = image.load_img('images/cat.jpg',
9                       target_size=(224, 224))
```

Bilderkennung

```
1  import tensorflow as tf
2  import numpy as np
3  from pprint import pprint
4
5  image = tf.contrib.keras.preprocessing.image
6  vgg16 = tf.contrib.keras.applications.vgg16
7  model = vgg16.VGG16()
8  img = image.load_img('images/cat.jpg',
9                       target_size=(224, 224))
10 x = image.img_to_array(img)
11 x = np.expand_dims(x, axis=0)
12 x = vgg16.preprocess_input(x)
```

Bilderkennung

```
1  import tensorflow as tf
2  import numpy as np
3  from pprint import pprint
4
5  image = tf.contrib.keras.preprocessing.image
6  vgg16 = tf.contrib.keras.applications.vgg16
7  model = vgg16.VGG16()
8  img = image.load_img('images/cat.jpg',
9                       target_size=(224, 224))
10 x = image.img_to_array(img)
11 x = np.expand_dims(x, axis=0)
12 x = vgg16.preprocess_input(x)
13 predictions = model.predict(x)
14 pprint(vgg16.decode_predictions(predictions))
```

Bilderkennung

https://en.wiktionary.org/wiki/cat#/media/File:Cat03.jpg

```
[[('n02123159', 'tiger_cat', 0.43690097),
('n02124075', 'Egyptian_cat', 0.32366198),
('n02123045', 'tabby', 0.1447085),
('n02127052', 'lynx', 0.019589322),
('n07930864', 'cup', 0.0077141393)]]
```

Intelligent
Embedded Systems

https://www.ies.uni-kassel.de/Soft_Computing

UDACITY

https://www.udacity.com/course/deep-learning--ud730

Q&A

Folien und Codebeispiele in Jupyter:

`https://github.com/flipdot/HackWat/tree/master/2018-06-02/tensorflow`