Universität Hamburg
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Fabian Barteld, Benjamin Milde, Prof. Dr. Chris Biemann

# TENSORFLOW – REGRESSION MODELS

# Linear Regression

# Linear Regression

- Given: $(x_1, y_1)$, ..., $(x_n, y_n)$
- Goal: find $w$ and $b$ such that

$$\hat{y}_i = wx_i + b$$

fits the data, i.e.

$$\arg\min_{w,b} \frac{\sum_{i=1}^{n} (\hat{y}_i - y_i)^2}{n}$$

# Define model parameters

Model: $\hat{y}_i = wx_i + b$

Parameters: $w$, $b$, tensors of rank $0$

```
w = tf.Variable(tf.ones([]),
    name="weight")
b = tf.Variable(tf.zeros([]),
    name="bias")
```

# Define the model

$$\begin{pmatrix} \hat{y}_1 \\ \vdots \\ \hat{y}_n \end{pmatrix} = \begin{pmatrix} x_1 \\ \vdots \\ x_n \end{pmatrix} \odot \begin{pmatrix} w \\ \vdots \\ w \end{pmatrix} + \begin{pmatrix} b \\ \vdots \\ b \end{pmatrix}$$

```
yhat = tf.add(tf.multiply(X, w), b)
```

The scalars *w* and *b* are converted into vectors of the same length as X (broadcast);

`https://www.tensorflow.org/performance/xla/broadcasting`

# Define the loss

$$\frac{\sum_{i=1}^{n}(\hat{y}_i - y_i)^2}{n}$$

```
loss = tf.reduce_mean(tf.square(yhat - Y))
```

# Optimization

```
## Optimizer
optimizer = tf.train.GradientDescentOptimizer(
  0.01 # learning rate
  ).minimize(loss)

with tf.Session() as sess:
  ## initalize parameters
  sess.run(tf.global_variables_initializer())

  for i in range(20):
      ## run one epoch
      sess.run(optimizer)
```

# Hands on

Do a linear regression to learn $y = 2x + 1$

```
X_data = np.array([1., 2., 3., 4., 5., 6.],
        dtype=np.float32).reshape(6, 1)
Y_data = 2*X_data + 1
```

# Multiple Linear Regression

# Defining the input

Tensorflow graphs use placholders for input values

```
input_dim = 13

X = tf.placeholder(tf.float32, [None, input_dim])
Y = tf.placeholder(tf.float32, [None, 1])
```

Defines placeholders for two tensors of rank 2,
the shape is [Number of examples, Dimension]

# Adapting the model

$$\begin{pmatrix} \hat{y}_1 \\ \vdots \\ \hat{y}_n \end{pmatrix} = \begin{pmatrix} x_{1,1} & \cdots & x_{1,input\_dim} \\ \vdots & & \vdots \\ x_{n,1} & \cdots & x_{n,input\_dim} \end{pmatrix} \times \begin{pmatrix} w_1 \\ \vdots \\ w_{input\_dim} \end{pmatrix} + \begin{pmatrix} b \\ \vdots \\ b \end{pmatrix}$$

```
w = tf.Variable(tf.ones(input_dim))
yhat = tf.add(tf.matmul(X, w), b)
```

# Getting data into the model

```
## Optimizer
optimizer = tf.train.GradientDescentOptimizer(
  0.01 # learning rate
  ).minimize(loss)

with tf.Session() as sess:
  ## initalize parameters
  sess.run(tf.global_variables_initializer())

  for i in range(20):
      ## run one epoch
      sess.run(optimizer, {X: data_X, Y: data_Y})
```

# Hands on

Do a multiple linear regression with Boston housing prices

```
from sklearn.datasets import load_boston
from sklearn.preprocessing import scale

data_X, data_Y = load_boston(True)
data_X = scale(data_X)
data_Y = data_Y.reshape(len(data_Y), 1)
```

# Logistic regression

# Classification with Logistic regression

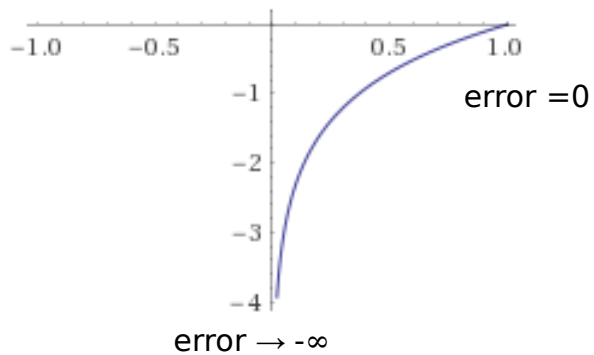
Binary classification, $y = 0$ or $y = 1$

$p_i = S(WX_i + b)$

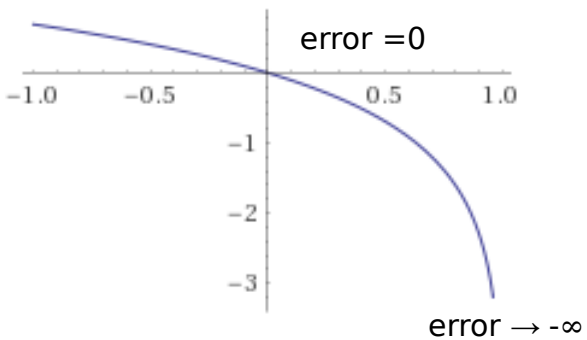
Loss (Binary-crossentropy):

$$-\frac{1}{N}\sum_{i=1}^{N}(y_i \log p_i + (1 - y_i)(\log 1 - p_i))$$

if y=1:




if y=0:



# Classification with Logistic regression

$p_i = S(WX_i + b)$

Loss (Binary-crossentropy):

$$-\frac{1}{N}\sum_{i=1}^{N}(y_i \log p_i + (1 - y_i)(\log 1 - p_i))$$

In tensorflow:

Don't use – numerical problems!

```
p = tf.sigmoid(yhat)
loss = -1.0 * tf.reduce_mean(y*tf.log(p) + (1-y)*tf.log(1-p))
```

# Classification with Logistic regression

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In tensorflow:

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```
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loss = -1.0 * tf.reduce_mean(y*tf.log(p) + (1-y)*tf.log(1-p))
```

Optimized version (Use this instead!)

```
loss = tf.reduce_mean(
  tf.nn.sigmoid_cross_entropy_with_logits(
      labels=y, logits=yhat))
```

# Scaling the input data

```
from sklearn.preprocessing import StandardScaler

scaler = StandardScaler()
scaler.fit(x_train)
x_train = scaler.transform(x_train)
x_test = scaler.transform(x_test)
```

# Hands on: Binary classification

Dataset: `http://scikit-learn.org/stable/modules/generated/sklearn.datasets.load_breast_cancer.html`

```
from sklearn.datasets import load_breast_cancer
from sklearn.model_selection import train_test_spli

## load the data
bc = load_breast_cancer()
x_data = bc['data']          # shape: (569,30)
y_data = bc['target'].reshape(
  len(bc['target']), 1) # shape: (569, 1)

x_train, x_test, y_train, y_test =
  train_test_split(x_data, y_data)
```

# One-hot encoding of nominal features

Names dataset `http://www.nltk.org/book/ch06.html`

```
def gender_features(word):
  return {'last_letter': word[-1]}

def gender_features(word):
  return {'suffix1': word[-1:],
          'suffix2': word[-2:]}
```

# One-hot encoding of nominal features

Names dataset `http://www.nltk.org/book/ch06.html`

```
def gender_features(word):
  return {'last_letter': word[-1]}

def gender_features(word):
  return {'suffix1': word[-1:],
          'suffix2': word[-2:]}
from sklearn.feature_extraction import DictVectoriz
feat_vectorizer = DictVectorizer(
  dtype=numpy.int32, sparse=False)
train_X = feat_vectorizer.fit_transform(
  train_feats)
test_X = feat_vectorizer.transform(test_feats)
```

# Stochastic gradient descent

```
with tf.Session() as sess:
    ## initalize parameters
    sess.run(tf.global_variables_initializer())

    for i in range(20):
        ## run one epoch
        ## update for each training example
        for x, y in zip(x_data, y_data):
            sess.run(optimizer, {X: x, Y: y})
```

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with tf.Session() as sess:
    ## initalize parameters
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    for i in range(20):
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        for x, y in zip(x_data, y_data):
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```

Usually the data is shuffled and
passed in small batches to the optimizer.

# Hands on

Fit a logistic regression model to the names dataset
`http://www.nltk.org/book/ch06.html`

```
import nltk
## names must be installed by running
## nltk.download('names')
from nltk.corpus import names
import random

labeled_names = (
  [(n, 0) for n in names.words('male.txt')] +
  [(n, 1) for n in names.words('female.txt')])
random.shuffle(labeled_names)
```