Neural Networks for Text Problems

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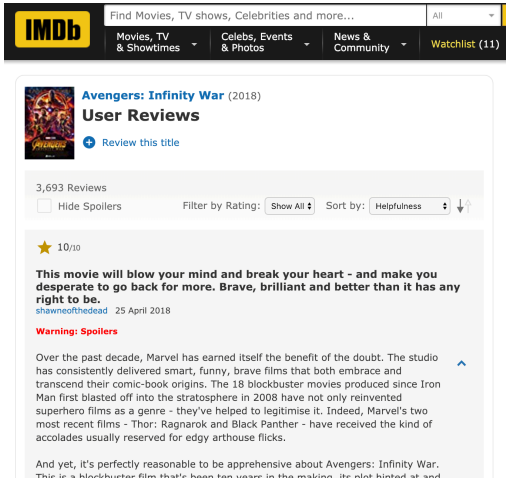
Preliminaries of Text Processing

The IMDB Movie Review Dataset

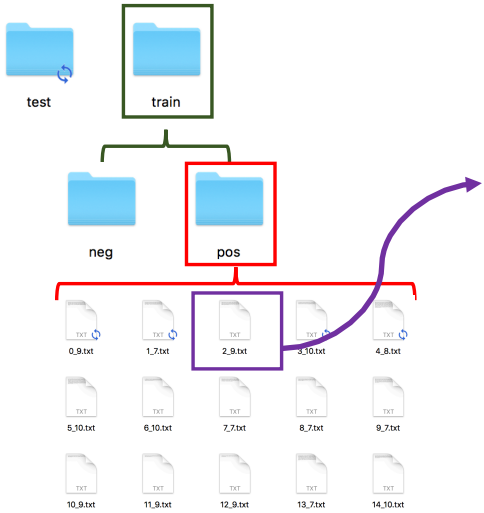


The IMDB Movie Review Dataset

- 50K movie reviews (text).
- Each review is labeled with either “positive” or “negative”.
- It is a binary classification problem.
- 25K for training and 25K for testing.

- Download from
  - http://ai.stanford.edu/~amaas/data/sentiment/
  - http://s3.amazonaws.com/text-datasets/aclImdb.zip

The IMDB Movie Review Dataset



2_9.txt

Bromwell High is nothing short of brilliant. Expertly scripted and perfectly delivered, this searing parody of a students and teachers at a South London Public School leaves you literally rolling with laughter. It's vulgar, provocative, witty and sharp. The characters are a superbly caricatured cross section of British society (or to be more accurate, of any society). Following the escapades of Keisha, Latrina and Natella, our three "protagonists" for want of a better term, the show doesn't shy away from parodying every imaginable subject. Political correctness flies out the window in every episode. If you enjoy shows that aren't afraid to poke fun of every taboo subject imaginable, then Bromwell High will not disappoint!

Represent Text by Vectors/Matrices

Goal: Build a binary classifier for predicting the sentiment of a movie review.

Task: Convert the $50K$ movie reviews (text) to $50K$ vectors (sequences).

- Why representing text by numeric vectors/matrices?
  - Classifiers (e.g., logistic regression, SVM, neural networks) do not "*understand*" text.
  - The input must be vectors, matrices, or tensors.

Task: Convert the $50K$ movie reviews (text) to $50K$ vectors (sequences).

Step 1: Load the text and labels to memory.

```
import os
imdb_dir = './aclImdb'
train_dir = os.path.join(imdb_dir, 'train')
labels_train = []
texts_train = []
for label_type in ['pos', 'neg']:
    dir_name = os.path.join(train_dir, label_type)
    for fname in os.listdir(dir_name):
        if fname[-4:] == '.txt':
            f = open(os.path.join(dir_name, fname))
            texts_train.append(f.read())
            f.close()
            if label_type == 'neg':
                labels_train.append(0)
            else:
                labels_train.append(1)
```

Task: Convert the $50K$ movie reviews (text) to $50K$ vectors (sequences).

Step 1: Load the text and labels to memory.

Results:

- `texts_train: list[string].`
  - Each `string` is a review.
- `labels_train: list[int].`
  - "1" means positive, and "0" means negative.

```
print('Number of training samples: ' + str(len(texts_train)))
print('Number of training labels: ' + str(len(labels_train)))
```

```
Number of training samples: 25000
Number of training labels: 25000
```

```
i = 0
print('label #' + str(i) + ': ' + str(labels_train[i]))
print('text  #' + str(i) + ':')
print(texts_train[i])
```

```
label #0: 1
text  #0:
For a movie that gets no respect there sure are a lot of memorable quotes listed for this gem. Imagine a movie where
Joe Piscopo is actually funny! Maureen Stapleton is a scene stealer. The Moroni character is an absolute scream. Watc
h for Alan "The Skipper" Hale jr. as a police Sgt.
```

Task: Convert the $50K$ movie reviews (text) to $50K$ vectors (sequences).

Step 2: Tokenize the text.

1. Split the text to tokens (word).
   - `tokens_train: list[list[string]]`.
   - Each `string` is a token (word).

```
tokens_train = []
for samples in texts_train:
    token_list = samples.split()
    token_list = [token.strip(',.!"') for token in token_list]
    tokens_train.append(token_list)
```

Task: Convert the $50K$ movie reviews (text) to $50K$ vectors (sequences).

Step 2: Tokenize the text.

1. Split the text to tokens (word).
   - `tokens_train: list[list[string]]`.
   - Each `string` is a token.

```
print(texts_train[i])
```

```
For a movie that gets no respect there sure are a lot of memorable quotes listed for this ge
m. Imagine a movie where Joe Piscopo is actually funny! Maureen Stapleton is a scene stealer.
The Moroni character is an absolute scream. Watch for Alan "The Skipper" Hale jr. as a police
Sgt.
```

```
print(tokens_train[i])
```

```
['For', 'a', 'movie', 'that', 'gets', 'no', 'respect', 'there', 'sure', 'are', 'a', 'lot', 'o
f', 'memorable', 'quotes', 'listed', 'for', 'this', 'gem', 'Imagine', 'a', 'movie', 'where',
'Joe', 'Piscopo', 'is', 'actually', 'funny', 'Maureen', 'Stapleton', 'is', 'a', 'scene', 'ste
aler', 'The', 'Moroni', 'character', 'is', 'an', 'absolute', 'scream', 'Watch', 'for', 'Ala
n', 'The', 'Skipper', 'Hale', 'jr', 'as', 'a', 'police', 'Sgt']
```

Task: Convert the $50K$ movie reviews (text) to $50K$ vectors (sequences).

Step 2: Tokenize the text.

1. Split the text to tokens (word).
2. Build a dictionary of tokens.
   - `token_index: dict[(string, int)]`.
   - Each `string` is a token (word).
   - Each `int` is an index.

```
token_index = {}
for token_list in tokens_train:
    for token in token_list:
        if token not in token_index:
            token_index[token] = len(token_index) + 1
```

Task: Convert the $50K$ movie reviews (text) to $50K$ vectors (sequences).

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1. Split the text to tokens (word).
2. Build a dictionary of tokens.
   - `token_index: dict[(string, int)]`.
   - Each `string` is a token (word).
   - Each `int` is an index.
   - The vocabulary size (number of unique tokens) is $175.8K$

```
print(len(token_index))
```

```
175837
```

```
token_index
```

Out[10]:

```
{'for': 1,
 'a': 2,
 'movie': 3,
 'that': 4,
 'gets': 5,
 'no': 6,
 'respect': 7,
 'there': 8,
 'sure': 9,
 'are': 10,
```

Task: Convert the $50K$ movie reviews (text) to $50K$ vectors (sequences).

Step 2: Tokenize the text.

1. Split the text to tokens (word).
2. Build a dictionary of tokens.
3. Remove the *stop words* (optional).
   - The most frequent words such as “the”, “a”, “to”, etc.

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All the training data we need:

- `tokens_train: list[list[string]].`
- `labels_train: list[int].`
- `token_index:  dict[(string, int)].`

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All the training data we need:

- `tokens_train: list[list[string]]` ⟹ `list[list[int]]`.
- `labels_train: list[int]`.
- `token_index: dict[(string, int)]`.

Task: Convert the $50K$ movie reviews (text) to $50K$ vectors (sequences).

Step 3: Encode the text: represent each token (word) by its index.

`sequence_train: list[list[int]].`

```
sequences_train = []
for token_list in tokens_train:
    sequence = [token_index[token] for token in token_list]
    sequences_train.append(sequence)
```

Task: Convert the $50K$ movie reviews (text) to $50K$ vectors (sequences).

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`sequence_train: list[list[int]].`

```
print(tokens_train[i])
```

```
['for', 'a', 'movie', 'that', 'gets', 'no', 'respect', 'there', 'sure',
'are', 'a', 'lot', 'of', 'memorable', 'quotes', 'listed', 'for', 'this',
'gem', 'imagine', 'a', 'movie', 'where', 'joe', 'piscopo', 'is', 'actuall
y', 'funny', 'maureen', 'stapleton', 'is', 'a', 'scene', 'stealer', 'th
e', 'moroni', 'character', 'is', 'an', 'absolute', 'scream', 'watch', 'fo
r', 'alan', 'the', 'skipper', 'hale', 'jr', 'as', 'a', 'police', 'sgt']
```

```
print(sequences_train[i])
```

```
[1, 2, 3, 4, 5, 6, 7, 8, 9, 10, 2, 11, 12, 13, 14, 15, 1, 16, 17, 18, 2,
3, 19, 20, 21, 22, 23, 24, 25, 26, 22, 2, 27, 28, 29, 30, 31, 22, 32, 33,
34, 35, 1, 36, 29, 37, 38, 39, 40, 2, 41, 42]
```

```
token_index
```

Out[10]:

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{'for': 1,
 'a': 2,
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3, 19, 20, 21, 22, 23, 24, 25, 26, 22, 2, 27, 28, 29, 30, 31, 22, 32, 33,
34, 35, 1, 36, 29, 37, 38, 39, 40, 2, 41, 42]
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Out[10]:

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```
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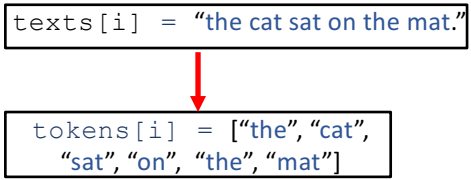

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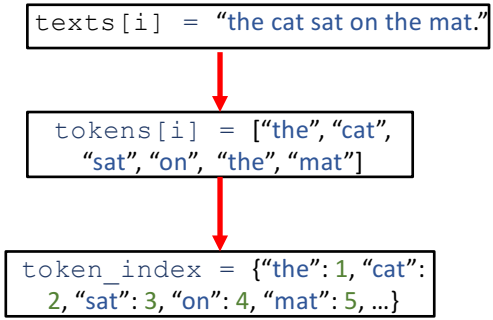

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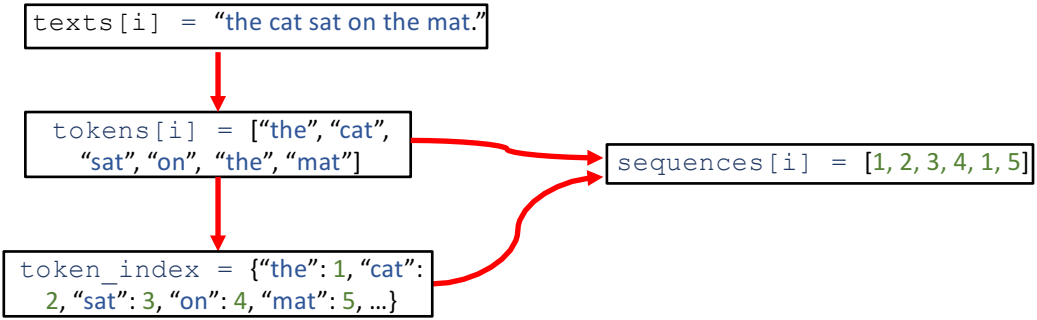

Task: Convert the $50K$ movie reviews (text) to $50K$ vectors (sequences).

Step 1: Load the text and labels to memory.

Step 2: Tokenize the text.

Step 3: Encode the text.

Step 4: Do the same for the test set.

- Use the same dictionary built on the training data.
- The dictionary for training and test must be the same!

Task: Convert the $50K$ movie reviews (text) to $50K$ vectors (sequences).

Result: $50K$ lists of integers; the i-th list has w_i items.

Problem: the training samples are not aligned (have different sizes, w_i).

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Solution:

- Cut off the texts to keep w words, e.g., $w = 7$.

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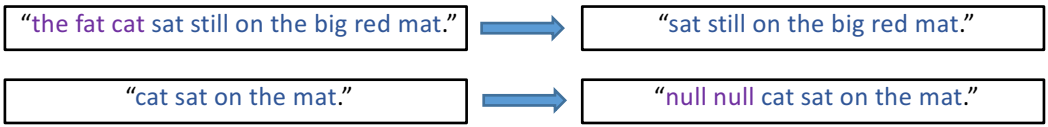
Problem: the training samples are not aligned (have different sizes, w_i).

Solution:

- Cut off the texts to keep w words, e.g., $w = 7$.
- If a text is shorter than w, pad it with zeros.



Task: Convert the $50K$ movie reviews (text) to $50K$ vectors (sequences).

Result: $50K$ lists of integers; every list has w items.

Text Processing in Keras

Task: Convert the $50K$ movie reviews (text) to $50K$ vectors (sequences).

Convert texts to sequences by Keras.

```
from keras.preprocessing.text import Tokenizer

vocabulary = 10000
tokenizer = Tokenizer(num_words=vocabulary)
tokenizer.fit_on_texts(texts_train)

word_index = tokenizer.word_index
sequences_train = tokenizer.texts_to_sequences(texts_train)
```

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```

- word_index: dict[(string, int)]
- sequence_train: list[list[int]]

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tokenizer.fit_on_texts(texts_train)

word_index = tokenizer.word_index
sequences_train = tokenizer.texts_to_sequences(texts_train)
```

- word_index: dict[(string, int)]
- sequence_train: list[list[int]]

```
print(sequences_train[0])
```

```
[15, 3, 17, 12, 211, 54, 1158, 47, 249, 23, 3, 173, 4, 903, 4381, 3559, 15, 11, 1525, 835, 3,
17, 118, 911, 6, 162, 160, 7262, 6, 3, 133, 1, 106, 6, 32, 1552, 2032, 103, 15, 1605, 1, 859
5, 1789, 14, 3, 565, 6259]
```

Task: Convert the $50K$ movie reviews (text) to $50K$ vectors (sequences).

Convert texts to sequences by Keras.

```
from keras import preprocessing

word_num = 20
x_train = preprocessing.sequence.pad_sequences(sequences_train, maxlen=word_num)
```

```
x_train.shape
```

```
(25000, 20)
```

```
x_train[0]
```

```
array([7262,    6,    3,  133,    1,  106,    6,   32, 1552, 2032,  103,
         15, 1605,    1, 8595, 1789,   14,    3,  565, 6259], dtype=int32)
```

Task: Convert the $50K$ movie reviews (text) to $50K$ vectors (sequences).

Result: A matrix of size `25K` × `word_num` (training). (The test is analogous.)

```
texts_train[0]
```

```
'For a movie that gets no respect there sure are a lot of memorable quotes listed for this ge
m. Imagine a movie where Joe Piscopo is actually funny! Maureen Stapleton is a scene stealer.
The Moroni character is an absolute scream. Watch for Alan "The Skipper" Hale jr. as a police
Sgt.'
```

```
x_train[0]
```

```
array([7262,    6,    3,  133,    1,  106,    6,   32, 1552, 2032,  103,
         15, 1605,    1, 8595, 1789,   14,    3,  565, 6259], dtype=int32)
```

Word Embedding: Sequence to Vectors

Represent Text by Vectors/Matrices

Goal: Build a binary classifier for predicting the sentiment of a movie review.

Task 1: Convert the $50K$ movie reviews (text) to $50K$ sequences (vectors).

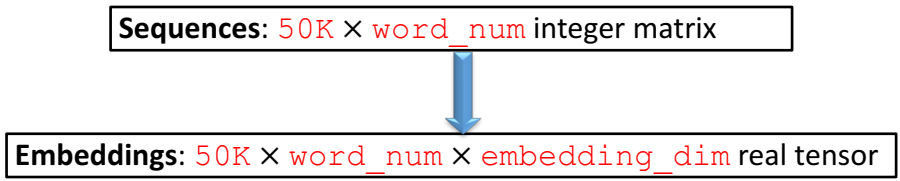
Sequences: `50K` × `word_num` integer matrix

Represent Text by Vectors/Matrices

Goal: Build a binary classifier for predicting the sentiment of a movie review.

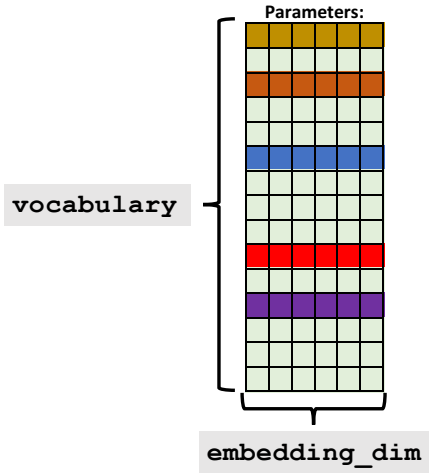
Task 1: Convert the $50K$ movie reviews (text) to $50K$ sequences (vectors).

Task 2: Word embedding: an index (of word) to a vector.



Task: Word embedding: an index (of word) to a vector.

- Learn a parameter matrix of size `vocabulary` × `embedding_dim`.



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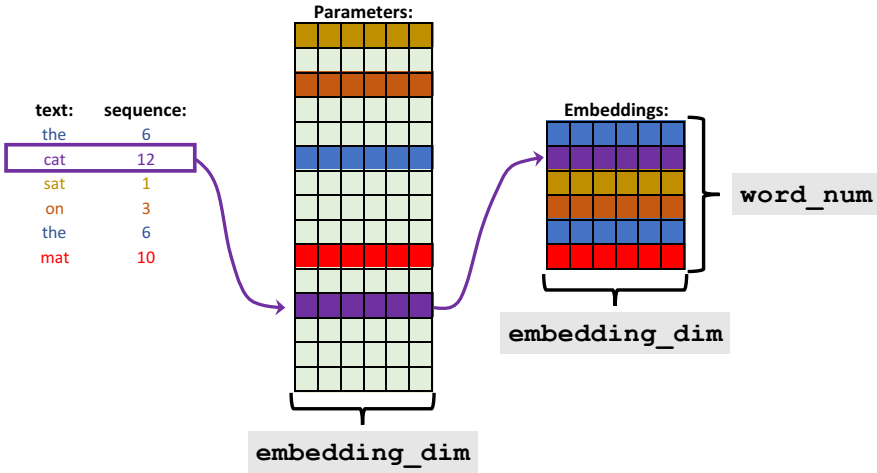
- Learn a parameter matrix of size `vocabulary` × `embedding_dim`.



Task: Word embedding: an index (of word) to a vector.

```
from keras.models import Sequential
from keras.layers import Flatten, Dense, Embedding

embedding_dim = 8

model.add(Embedding(vocabulary, embedding_dim, input_length=word_num))
```

$= 10K$ $= 8$ $= 20$

```
_________________________________________________________________
Layer (type)                 Output Shape              Param #
=================================================================
embedding_1 (Embedding)      (None, 20, 8)             80000
```

$=$ vocabulary $\times$ embedding_dim

word_num embedding_dim

Logistic Regression for Binary Classification

Represent Text by Vectors/Matrices

Goal: Build a binary classifier for predicting the sentiment of a movie review.

Task 1: Convert the $50K$ movie reviews (text) to $50K$ sequences (vectors).

Task 2: Word embedding: an index (of word) to a vector.

Task 3: Binary classification using a neural network.

Task: Word embedding: an index (of word) to a vector.

```
from keras.models import Sequential
from keras.layers import Flatten, Dense, Embedding

embedding_dim = 8

model = Sequential()
model.add(Embedding(vocabulary, embedding_dim, input_length=word_num))
model.add(Flatten())
model.add(Dense(1, activation='sigmoid'))

model.summary()
```

```
_________________________________________________________________
Layer (type)                 Output Shape              Param #
=================================================================
embedding_1 (Embedding)      (None, 20, 8)             80000
_________________________________________________________________
flatten_1 (Flatten)          (None, 160)               0
_________________________________________________________________
dense_1 (Dense)              (None, 1)                 161
=================================================================
Total params: 80,161
Trainable params: 80,161
Non-trainable params: 0
```

Task: Binary classification using a neural network.

```
from keras import optimizers

epochs = 50

model.compile(optimizer=optimizers.RMSprop(lr=0.0001),
              loss='binary_crossentropy', metrics=['acc'])
```

Task: Binary classification using a neural network.

```
from keras import optimizers

epochs = 50

model.compile(optimizer=optimizers.RMSprop(lr=0.0001),
              loss='binary_crossentropy', metrics=['acc'])
history = model.fit(x_train, y_train, epochs=epochs,
                    batch_size=32, validation_data=(x_valid, y_valid))
```

- The training set is randomly split to a training set and a validation set.
- 80% for training and 20% for validation.

Task: Binary classification using a neural network.

```
from keras import optimizers

epochs = 50

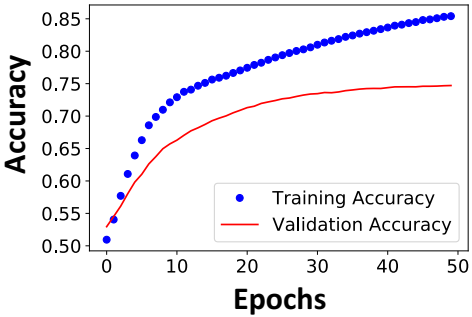
model.compile(optimizer=optimizers.RMSprop(lr=0.0001),
              loss='binary_crossentropy', metrics=['acc'])
history = model.fit(x_train, y_train, epochs=epochs,
                    batch_size=32, validation_data=(x_valid, y_valid))
```

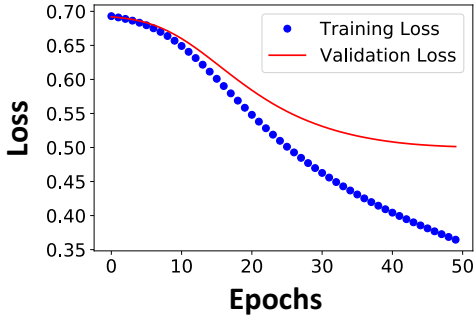
```
Epoch 1/50
12500/12500 [==============================] - 1s 74us/step - loss: 0.6930 - acc: 0.5094 - val_loss: 0.6919 - val_acc: 0.5295
Epoch 2/50
12500/12500 [==============================] - 1s 60us/step - loss: 0.6911 - acc: 0.5405 - val_loss: 0.6910 - val_acc: 0.5452
Epoch 3/50
12500/12500 [==============================] - 1s 57us/step - loss: 0.6889 - acc: 0.5770 - val_loss: 0.6898 - val_acc: 0.5612
```

-
-
-

```
Epoch 49/50
12500/12500 [==============================] - 1s 56us/step - loss: 0.3686 - acc: 0.8530 - val_loss: 0.5017 - val_acc: 0.7468
Epoch 50/50
12500/12500 [==============================] - 1s 56us/step - loss: 0.3646 - acc: 0.8541 - val_loss: 0.5014 - val_acc: 0.7471
```

Task: Binary classification using a neural network.





Task: Binary classification using a neural network.

Processing the test set: load the data to memory.

```
import os
imdb_dir = './aclImdb'
test_dir = os.path.join(imdb_dir, 'test')
labels_test = []
texts_test = []
for label_type in ['pos', 'neg']:
    dir_name = os.path.join(test_dir, label_type)
    for fname in os.listdir(dir_name):
        if fname[-4:] == '.txt':
            f = open(os.path.join(dir_name, fname))
            texts_test.append(f.read())
            f.close()
            if label_type == 'neg':
                labels_test.append(0)
            else:
                labels_test.append(1)
```

Task: Binary classification using a neural network.

Processing the test set: convert **text** to **tokens** and then **sequence**.

```
# Do NOT fit the Tokenizer again!!!
#tokenizer = Tokenizer(num_words=vocabulary)
#tokenizer.fit_on_texts(texts_train)
word_index = tokenizer.word_index
sequences_test = tokenizer.texts_to_sequences(texts_test)
```

```
from keras import preprocessing

word_num = 20
x_test = preprocessing.sequence.pad_sequences(sequences_test, maxlen=word_num)
```

Task: Binary classification using a neural network.

Evaluate the model on the test set.

```
loss_and_acc = model.evaluate(x_test, labels_test)
print('loss = ' + str(loss_and_acc[0]))
print('acc = ' + str(loss_and_acc[1]))
```

```
25000/25000 [==============================] - 0s 18us/step
loss = 0.5025235502243042
acc = 0.74928
```

- About 75% accuracy on the test set.
- Not bad, because we just use the last 20 words in each movie review. (`word_num=20`)