Advanced techniques

Practice Session 5

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Outline

Will learn how to apply the advanced techniques:

Generalization techniques

regularization, early stopping, dropout

Weight initialization

He’s initialization

Techniques for training stability

batch normalization, learning rate decaying

Start with a two-layer DNN

```
from tensorflow.keras.models import Sequential
from tensorflow.keras.layers import Dense
from tensorflow.keras.optimizers import Adam

model = Sequential()
model.add(Dense(128, activation='relu'))
model.add(Dense(1, activation='sigmoid'))

opt = Adam(learning_rate=0.01,
           beta_1 = 0.9,
           beta_2 = 0.999)

model.compile(optimizer=opt,
              loss='binary_crossentropy',
              metrics=['acc'])
```

Training

```
model.fit(X_train,y_train, epochs=10)
```

```
Epoch 1/10
814/814 [==============================] - 1s 527us/step - loss: 0.3559 - acc:
0.8342
Epoch 2/10
814/814 [==============================] - 0s 528us/step - loss: 0.3224 - acc:
0.8507
Epoch 3/10
814/814 [==============================] - 0s 526us/step - loss: 0.3198 - acc:
0.8505
Epoch 4/10
814/814 [==============================] - 0s 524us/step - loss: 0.3158 - acc:
0.8520
Epoch 5/10
814/814 [==============================] - 0s 519us/step - loss: 0.3155 - acc:
0.8516
Epoch 6/10
814/814 [==============================] - 0s 523us/step - loss: 0.3134 - acc:
0.8545
Epoch 7/10
814/814 [==============================] - 0s 522us/step - loss: 0.3111 - acc:
0.8567
Epoch 8/10
814/814 [==============================] - 0s 527us/step - loss: 0.3102 - acc:
0.8555
Epoch 9/10
814/814 [==============================] - 0s 522us/step - loss: 0.3081 - acc:
0.8576
Epoch 10/10
814/814 [==============================] - 0s 544us/step - loss: 0.3043 - acc:
0.8594
```

Evaluation

```
val_hist = model.evaluate(X_val,y_val)

print(val_hist)
```

```
102/102 [==============================] - 0s 559us/step - loss: 0.3249 - acc:
0.8566
[0.32488954067230225, 0.8565725088119507]
```

Regularization

```
from tensorflow.keras.regularizers import l2


model = Sequential()


model.add(Dense(128,
          kernel_regularizer=l2(0.01),
          bias_regularizer=l2(0.01)))
```

for weights

regularization factor

for bias

Early stopping

```
from tensorflow.keras.callbacks import EarlyStopping
model = Sequential()
model.add(Dense(128,kernel_regularizer=l2(0.01),
          bias_regularizer=l2(0.01),
          activation='relu'))
model.add(Dense(1,kernel_regularizer=l2(0.01),
          bias_regularizer=l2(0.01),
          activation='sigmoid'))
opt = Adam(learning_rate=0.01,beta_1 = 0.9,beta_2 = 0.999)
model.compile(optimizer=opt,
              loss='binary_crossentropy')
es_callback = EarlyStopping(monitor='val_loss', patience=2)
hist = model.fit(X_train, y_train,
                 validation_data=(X_val, y_val),
                 epochs=100,callbacks=[es_callback])
```

# of epochs with no improvement after which training will stop.

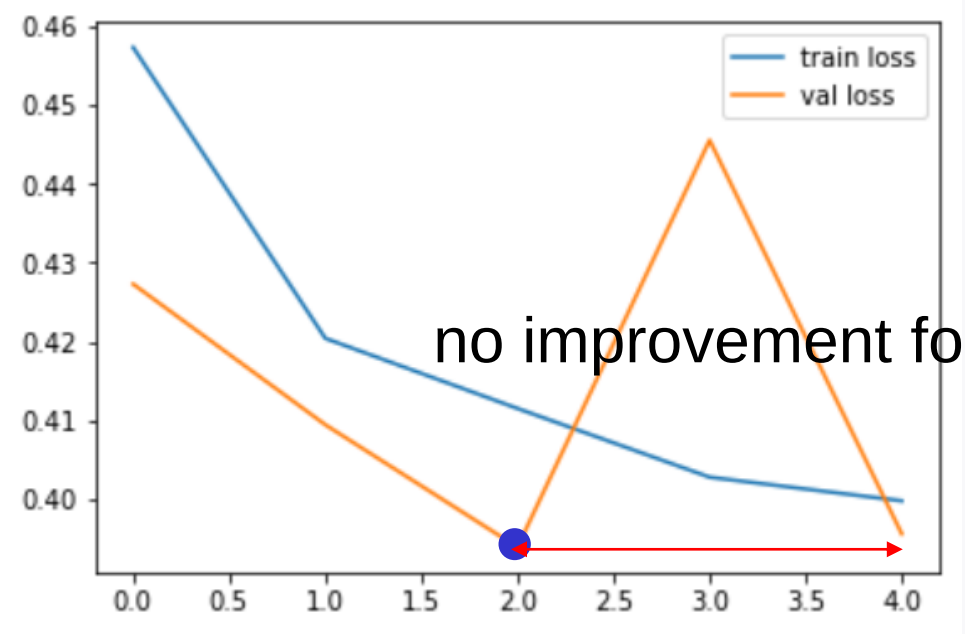
Early stopping: patience=2

```
Epoch 1/100
814/814 [==============================] - 1s 659us/step - loss: 0.4573 - val_loss: 0.4273
Epoch 2/100
814/814 [==============================] - 0s 590us/step - loss: 0.4204 - val_loss: 0.4095
Epoch 3/100
814/814 [==============================] - 0s 586us/step - loss: 0.4115 - val_loss: 0.3940
Epoch 4/100
814/814 [==============================] - 0s 582us/step - loss: 0.4028 - val_loss: 0.4456
Epoch 5/100
814/814 [==============================] - 0s 586us/step - loss: 0.3998 - val_loss: 0.3956
```

no improvement for 2 epochs

Early stopping: patience=2

```
train_loss = hist.history['loss']
val_loss = hist.history['val_loss']

import matplotlib.pyplot as plt

plt.plot(train_loss,label='train loss')
plt.plot(val_loss,label='val loss')
plt.legend()
plt.show()
```



no improvement for 2 epochs

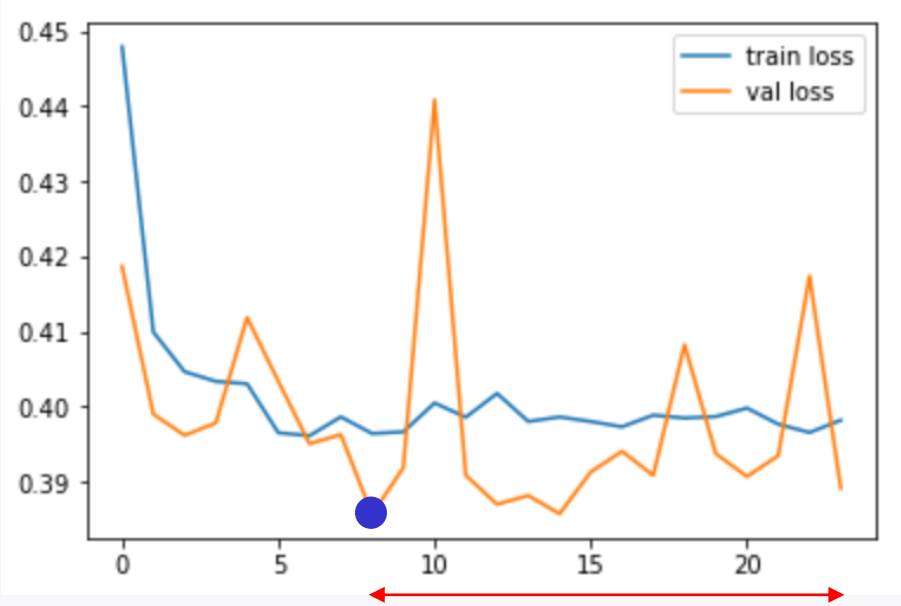
Early stopping: patience=15

```
Epoch 1/100
814/814 [==============================] - 1s 672us/step - loss: 0.4479 - val_loss: 0.4187
Epoch 2/100
814/814 [==============================] - 0s 600us/step - loss: 0.4099 - val_loss: 0.3990
Epoch 3/100
814/814 [==============================] - 0s 573us/step - loss: 0.4047 - val_loss: 0.3962
Epoch 4/100
814/814 [==============================] - 0s 593us/step - loss: 0.4034 - val_loss: 0.3978
Epoch 5/100
814/814 [==============================] - 0s 577us/step - loss: 0.4031 - val_loss: 0.4119
Epoch 6/100
814/814 [==============================] - 0s 604us/step - loss: 0.3965 - val_loss: 0.4034
Epoch 7/100
814/814 [==============================] - 1s 679us/step - loss: 0.3961 - val_loss: 0.3951
Epoch 8/100
814/814 [==============================] - 1s 890us/step - loss: 0.3987 - val_loss: 0.3963
Epoch 9/100
814/814 [==============================] - 1s 671us/step - loss: 0.3964 - val_loss: 0.3857
Epoch 10/100
814/814 [==============================] - 1s 652us/step - loss: 0.3967 - val_loss: 0.3919
Epoch 11/100
814/814 [==============================] - 0s 587us/step - loss: 0.4005 - val_loss: 0.4409
Epoch 12/100
814/814 [==============================] - 1s 711us/step - loss: 0.3986 - val_loss: 0.3909
Epoch 13/100
814/814 [==============================] - 1s 616us/step - loss: 0.4018 - val_loss: 0.3870
Epoch 14/100
814/814 [==============================] - 1s 653us/step - loss: 0.3980 - val_loss: 0.3882
Epoch 15/100
814/814 [==============================] - 0s 578us/step - loss: 0.3986 - val_loss: 0.3857
Epoch 16/100
814/814 [==============================] - 0s 593us/step - loss: 0.3980 - val_loss: 0.3915
Epoch 17/100
814/814 [==============================] - 0s 590us/step - loss: 0.3973 - val_loss: 0.3941
Epoch 18/100
814/814 [==============================] - 0s 589us/step - loss: 0.3989 - val_loss: 0.3909
Epoch 19/100
814/814 [==============================] - 0s 576us/step - loss: 0.3985 - val_loss: 0.4083
Epoch 20/100
814/814 [==============================] - 0s 584us/step - loss: 0.3987 - val_loss: 0.3938
Epoch 21/100
814/814 [==============================] - 0s 592us/step - loss: 0.3998 - val_loss: 0.3907
Epoch 22/100
814/814 [==============================] - 0s 593us/step - loss: 0.3977 - val_loss: 0.3935
Epoch 23/100
814/814 [==============================] - 0s 580us/step - loss: 0.3966 - val_loss: 0.4174
Epoch 24/100
814/814 [==============================] - 0s 586us/step - loss: 0.3982 - val_loss: 0.3892
```

no improvement for 15 epochs

Early stopping: patience=15

```
train_loss = hist.history['loss']
val_loss = hist.history['val_loss']

import matplotlib.pyplot as plt

plt.plot(train_loss,label='train loss')
plt.plot(val_loss,label='val loss')
plt.legend()
plt.show()
```



no improvement for 15 epochs

Dropout

```
from tensorflow.keras.layers import Dropout

model = Sequential()
model.add(Dense(128,kernel_regularizer=l2(0.01),
          bias_regularizer=l2(0.01),
          activation='relu'))

model.add(Dropout(0.9))
```

dropout rate

Weight initialization

```
from tensorflow.keras.initializers import HeNormal
```

```
init = HeNormal()
```

```
model.add(Dense(128,kernel_regularizer=l2(0.01),
          bias_regularizer=l2(0.01),
          kernel_initializer=init,
          activation='relu'))
```

initializer setup

Batch normalization

```
from tensorflow.keras.layers import BatchNormalization
from tensorflow.keras.layers import ReLU

init = HeNormal()

model.add(Dense(128,kernel_regularizer=l2(0.01),
          bias_regularizer=l2(0.01),
          kernel_initializer=init))

model.add(BatchNormalization())

model.add(ReLU())
```

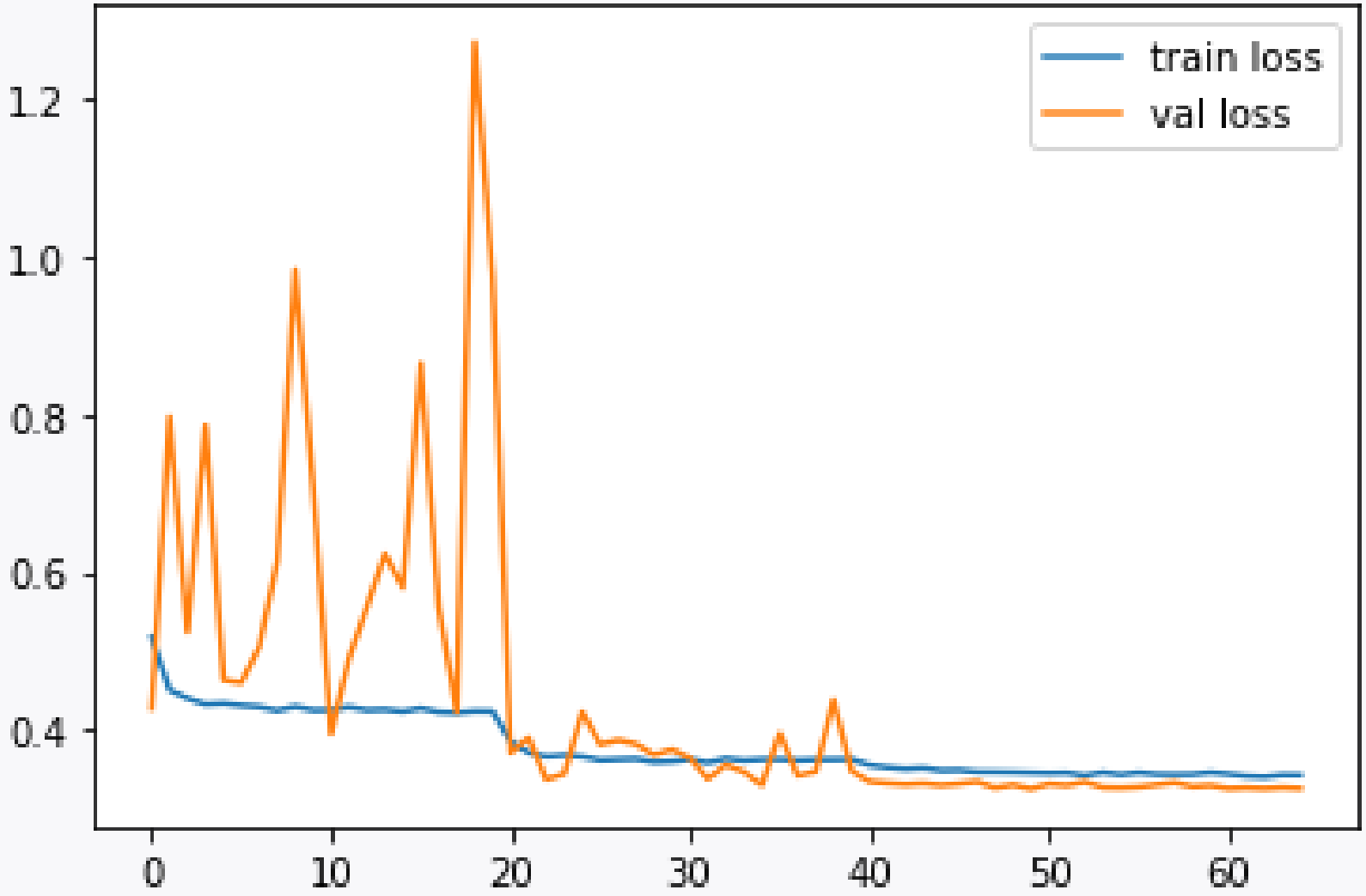
← prior to activation

Learning rate decaying

```
from tensorflow.keras.callbacks import LearningRateScheduler

def scheduler(epoch, lr):
    if epoch in [20,40,60]:
        lr = 0.1*lr
    else:
        lr = lr
    return lr

ls_callback = LearningRateScheduler(scheduler)

hist = model.fit(X_train, y_train,
                 validation_data=(X_val, y_val),
                 epochs=100, callbacks=[es_callback,ls_callback])
```

position

Learning rate decaying



Look ahead

Will learn how to implement **cross validation**.