### Fundamentals of Deep Learning

# The Learning Rate (α)

### What is the Learning Rate?

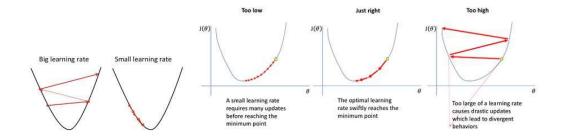
 Learning rate (α) is the magnitude of change made to model weights during backpropagation when the neural network is trained.

## How is the Learning Rate set?

 Learning rate (α) is specified as a hyperparameter with the optimizer (SGD,Adam. etc.)

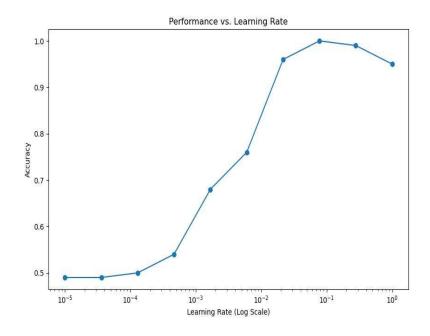
> model.compile(optimizer=tf.keras.optimizers.Adam(learning\_rate=0.001), loss=tf.keras.losses.CategoricalCrossentropy())

### How do we decide the Learning Rate value?



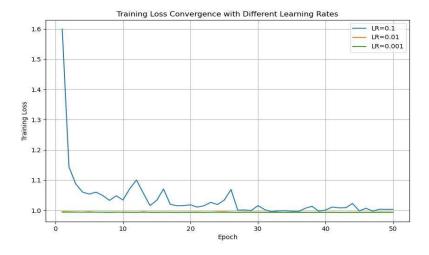
A commonly used default learning rate value is 0.001 (or 1e-3).

- If learning rate is too small, training will be very slow, and if it is too
   high, we might overshoot the minima.
- We can use learning rate range test, grid search, random search etc.
   to identify the optimal learning rate.
- Learning rate can also be dynamically adjusted.



# How can learning rate be adjusted dynamically?

We use a <u>learning rate scheduler</u> which makes pre-specified adjustments to the learning rate at specified intervals during the training procedure.



Adjusting the learning rate is done by decaying (reducing) the learning rate.

 We can find the ideal value of learning rate which gives the better training loss convergence.

# What are the learning rate schedules in Keras?

Keras has the following schedules:

#### 1) Constant Learning Rate

- The momentum and decay rate is zero.
- LR remains same.
- This is used as a baseline.

#### 2) Time based decay Learning Rate Scheduler

- The scheduler takes the decay rate (k) as a parameter.
- Keras updates the learning rate after every batch update.
- The learning rate is updated considering the decay rate (k), and total number of steps per epoch (t):

$$LR = \frac{LR_{initial}}{1+k*t}$$

#### 3) Step based decay learning rate scheduler

- The scheduler decreases the learning rate by a factor every few epochs.
- The factor, similar to decay rate, and the step size i.e. how often to update the LR, are provided by the user.
- The learning rate is updated as:

$$LR = LR_{initial} * factor \left\lfloor \frac{current-epoch}{step-size} \right\rfloor$$

#### 4) Exponential decay learning rate scheduler

• We define an exponential decay function and pass it to LR Scheduler:

$$LR = LR_{initial} * e^{(-1*k*t)}$$

### 5) Custom learning rate

 You can define your own learning rate function by subclassing tf.keras.callbacks.Callback and overriding the on\_epoch\_begin or on\_batch\_begin method.

```
mport tensorflow as tf
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    def __init__(self, initial_learning_rate, decay_steps, decay_rate):
       super(CustomLearningRateScheduler, self).__init__()
       self.initial_learning_rate = initial_learning_rate
       self.decay_steps = decay_steps
       self.decay_rate = decay_rate
    def __call__(self, step):
       return self.initial_learning_rate * tf.math.pow(self.decay_rate, (step / self.decay_steps))
initial_learning_rate = 0.1
decay_steps = 1000
decay_rate = 0.96
lr_schedule = CustomLearningRateScheduler(initial_learning_rate, decay_steps, decay_rate)
optimizer = tf.keras.optimizers.Adam(learning_rate=lr_schedule)
# Build and compile your model
model = tf.keras.models.Sequential([...])
 model.compile(optimizer=optimizer, loss='sparse_categorical_crossentropy', metrics=['accuracy'])
```