Practica

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For this assignment, I will build a DNN model based on the IRIS dataset based on the pdf I found in BB. I made sure first to install all the libraries needed for this project before I start.

I divided this project in the following steps:

1. Load the libraries.

# **1. Load the libraries**

library(keras) #Load Keras Library  
library(tensorflow) #Load Tensorflow  
# Set seed for reproducibility  
tensorflow::set\_random\_seed(1)

# **2. Prepare the dataset**

data <- iris[sample(nrow(iris)), ] # shuffle rows and randomize order of samples.  
x <- data[, 1:4] #This separates the features  
y <- data$Species #Separates species column.  
  
# Normalize features to [0,1]  
x <- as.matrix(apply(x, 2, function(col) (col - min(col)) / (max(col) - min(col))))  
  
  
y <- to\_categorical(as.integer(as.factor(y)) - 1, num\_classes = 3) # Convert lables to integers and then apple One-hot encoding.

# **3. Build the model.**

model <- keras\_model\_sequential() %>% #Define a sequential DNN model.  
 layer\_dense(units = 10, activation = "relu", input\_shape = ncol(x)) %>% #Input plus first hidden layer  
 layer\_dense(units = 10, activation = "relu") %>% #Second hidden layer  
 layer\_dense(units = 3, activation = "softmax") #output layer(3 classes)

# **4. Compile the model.**

model %>% compile( #Compile function  
 loss = "categorical\_crossentropy",  
 optimizer = "adam", #efficient adaptive optimizer.   
 metrics = "accuracy" #This track the accuracy during training.  
)

# **5. Train the model**

fit <- model %>% fit( #train the model  
 x = x, #Features  
 y = y, #one-hot encoded labels.   
 shuffle = TRUE, #Shuffle data before each epoch  
 batch\_size = 5, #batch size  
 validation\_split = 0.3, #30% for validation  
 epochs = 200 #Number of training epochs  
)

## Epoch 1/200  
## 21/21 - 3s - loss: 1.1854 - accuracy: 0.3333 - val\_loss: 1.1386 - val\_accuracy: 0.3333 - 3s/epoch - 129ms/step  
## Epoch 2/200  
## 21/21 - 0s - loss: 1.1486 - accuracy: 0.3333 - val\_loss: 1.1158 - val\_accuracy: 0.3333 - 223ms/epoch - 11ms/step  
## Epoch 3/200  
## 21/21 - 0s - loss: 1.1216 - accuracy: 0.3238 - val\_loss: 1.1009 - val\_accuracy: 0.3333 - 164ms/epoch - 8ms/step  
## Epoch 4/200  
## 21/21 - 0s - loss: 1.1017 - accuracy: 0.3048 - val\_loss: 1.0901 - val\_accuracy: 0.3556 - 163ms/epoch - 8ms/step  
## Epoch 5/200  
## 21/21 - 0s - loss: 1.0862 - accuracy: 0.3333 - val\_loss: 1.0797 - val\_accuracy: 0.5111 - 180ms/epoch - 9ms/step  
## Epoch 6/200  
## 21/21 - 0s - loss: 1.0668 - accuracy: 0.5429 - val\_loss: 1.0621 - val\_accuracy: 0.6000 - 181ms/epoch - 9ms/step  
## Epoch 7/200  
## 21/21 - 0s - loss: 1.0420 - accuracy: 0.6476 - val\_loss: 1.0369 - val\_accuracy: 0.6222 - 277ms/epoch - 13ms/step  
## Epoch 8/200  
## 21/21 - 0s - loss: 1.0063 - accuracy: 0.6857 - val\_loss: 0.9961 - val\_accuracy: 0.6222 - 174ms/epoch - 8ms/step  
## Epoch 9/200  
## 21/21 - 0s - loss: 0.9562 - accuracy: 0.6857 - val\_loss: 0.9520 - val\_accuracy: 0.6222 - 178ms/epoch - 8ms/step  
## Epoch 10/200  
## 21/21 - 0s - loss: 0.9016 - accuracy: 0.6857 - val\_loss: 0.9036 - val\_accuracy: 0.6222 - 187ms/epoch - 9ms/step  
## Epoch 11/200  
## 21/21 - 0s - loss: 0.8460 - accuracy: 0.6857 - val\_loss: 0.8517 - val\_accuracy: 0.6222 - 210ms/epoch - 10ms/step  
## Epoch 12/200  
## 21/21 - 0s - loss: 0.7892 - accuracy: 0.6857 - val\_loss: 0.8013 - val\_accuracy: 0.6222 - 205ms/epoch - 10ms/step  
## Epoch 13/200  
## 21/21 - 0s - loss: 0.7360 - accuracy: 0.6857 - val\_loss: 0.7558 - val\_accuracy: 0.6222 - 181ms/epoch - 9ms/step  
## Epoch 14/200  
## 21/21 - 0s - loss: 0.6889 - accuracy: 0.6857 - val\_loss: 0.7173 - val\_accuracy: 0.6222 - 193ms/epoch - 9ms/step  
## Epoch 15/200  
## 21/21 - 0s - loss: 0.6509 - accuracy: 0.6857 - val\_loss: 0.6845 - val\_accuracy: 0.6222 - 162ms/epoch - 8ms/step  
## Epoch 16/200  
## 21/21 - 0s - loss: 0.6193 - accuracy: 0.6857 - val\_loss: 0.6575 - val\_accuracy: 0.6222 - 168ms/epoch - 8ms/step  
## Epoch 17/200  
## 21/21 - 0s - loss: 0.5936 - accuracy: 0.6857 - val\_loss: 0.6341 - val\_accuracy: 0.6222 - 177ms/epoch - 8ms/step  
## Epoch 18/200  
## 21/21 - 0s - loss: 0.5705 - accuracy: 0.6857 - val\_loss: 0.6121 - val\_accuracy: 0.6222 - 172ms/epoch - 8ms/step  
## Epoch 19/200  
## 21/21 - 0s - loss: 0.5506 - accuracy: 0.6857 - val\_loss: 0.5944 - val\_accuracy: 0.6222 - 215ms/epoch - 10ms/step  
## Epoch 20/200  
## 21/21 - 0s - loss: 0.5327 - accuracy: 0.6857 - val\_loss: 0.5755 - val\_accuracy: 0.6222 - 179ms/epoch - 9ms/step  
## Epoch 21/200  
## 21/21 - 0s - loss: 0.5154 - accuracy: 0.6952 - val\_loss: 0.5568 - val\_accuracy: 0.6444 - 152ms/epoch - 7ms/step  
## Epoch 22/200  
## 21/21 - 0s - loss: 0.5000 - accuracy: 0.7048 - val\_loss: 0.5392 - val\_accuracy: 0.7111 - 161ms/epoch - 8ms/step  
## Epoch 23/200  
## 21/21 - 0s - loss: 0.4831 - accuracy: 0.7048 - val\_loss: 0.5240 - val\_accuracy: 0.7111 - 165ms/epoch - 8ms/step  
## Epoch 24/200  
## 21/21 - 0s - loss: 0.4651 - accuracy: 0.7429 - val\_loss: 0.5051 - val\_accuracy: 0.7556 - 157ms/epoch - 7ms/step  
## Epoch 25/200  
## 21/21 - 0s - loss: 0.4494 - accuracy: 0.8286 - val\_loss: 0.4873 - val\_accuracy: 0.7778 - 175ms/epoch - 8ms/step  
## Epoch 26/200  
## 21/21 - 0s - loss: 0.4332 - accuracy: 0.8476 - val\_loss: 0.4728 - val\_accuracy: 0.7778 - 174ms/epoch - 8ms/step  
## Epoch 27/200  
## 21/21 - 0s - loss: 0.4180 - accuracy: 0.8667 - val\_loss: 0.4559 - val\_accuracy: 0.8444 - 159ms/epoch - 8ms/step  
## Epoch 28/200  
## 21/21 - 0s - loss: 0.4072 - accuracy: 0.8762 - val\_loss: 0.4375 - val\_accuracy: 0.9111 - 158ms/epoch - 8ms/step  
## Epoch 29/200  
## 21/21 - 0s - loss: 0.3896 - accuracy: 0.8762 - val\_loss: 0.4265 - val\_accuracy: 0.8889 - 170ms/epoch - 8ms/step  
## Epoch 30/200  
## 21/21 - 0s - loss: 0.3781 - accuracy: 0.9048 - val\_loss: 0.4104 - val\_accuracy: 0.9333 - 164ms/epoch - 8ms/step  
## Epoch 31/200  
## 21/21 - 0s - loss: 0.3636 - accuracy: 0.8952 - val\_loss: 0.3978 - val\_accuracy: 0.9333 - 167ms/epoch - 8ms/step  
## Epoch 32/200  
## 21/21 - 0s - loss: 0.3519 - accuracy: 0.9143 - val\_loss: 0.3830 - val\_accuracy: 0.9556 - 175ms/epoch - 8ms/step  
## Epoch 33/200  
## 21/21 - 0s - loss: 0.3408 - accuracy: 0.9429 - val\_loss: 0.3705 - val\_accuracy: 0.9556 - 169ms/epoch - 8ms/step  
## Epoch 34/200  
## 21/21 - 0s - loss: 0.3302 - accuracy: 0.9238 - val\_loss: 0.3606 - val\_accuracy: 0.9556 - 173ms/epoch - 8ms/step  
## Epoch 35/200  
## 21/21 - 0s - loss: 0.3191 - accuracy: 0.9333 - val\_loss: 0.3485 - val\_accuracy: 0.9556 - 168ms/epoch - 8ms/step  
## Epoch 36/200  
## 21/21 - 0s - loss: 0.3110 - accuracy: 0.9333 - val\_loss: 0.3381 - val\_accuracy: 0.9556 - 171ms/epoch - 8ms/step  
## Epoch 37/200  
## 21/21 - 0s - loss: 0.2992 - accuracy: 0.9429 - val\_loss: 0.3280 - val\_accuracy: 0.9556 - 186ms/epoch - 9ms/step  
## Epoch 38/200  
## 21/21 - 0s - loss: 0.2953 - accuracy: 0.9238 - val\_loss: 0.3172 - val\_accuracy: 0.9333 - 158ms/epoch - 8ms/step  
## Epoch 39/200  
## 21/21 - 0s - loss: 0.2793 - accuracy: 0.9429 - val\_loss: 0.3113 - val\_accuracy: 0.9556 - 157ms/epoch - 7ms/step  
## Epoch 40/200  
## 21/21 - 0s - loss: 0.2719 - accuracy: 0.9524 - val\_loss: 0.3009 - val\_accuracy: 0.9556 - 205ms/epoch - 10ms/step  
## Epoch 41/200  
## 21/21 - 0s - loss: 0.2634 - accuracy: 0.9333 - val\_loss: 0.2925 - val\_accuracy: 0.9333 - 167ms/epoch - 8ms/step  
## Epoch 42/200  
## 21/21 - 0s - loss: 0.2569 - accuracy: 0.9429 - val\_loss: 0.2852 - val\_accuracy: 0.9333 - 165ms/epoch - 8ms/step  
## Epoch 43/200  
## 21/21 - 0s - loss: 0.2484 - accuracy: 0.9429 - val\_loss: 0.2778 - val\_accuracy: 0.9333 - 166ms/epoch - 8ms/step  
## Epoch 44/200  
## 21/21 - 0s - loss: 0.2423 - accuracy: 0.9429 - val\_loss: 0.2704 - val\_accuracy: 0.9556 - 205ms/epoch - 10ms/step  
## Epoch 45/200  
## 21/21 - 0s - loss: 0.2368 - accuracy: 0.9429 - val\_loss: 0.2634 - val\_accuracy: 0.9556 - 171ms/epoch - 8ms/step  
## Epoch 46/200  
## 21/21 - 0s - loss: 0.2283 - accuracy: 0.9429 - val\_loss: 0.2577 - val\_accuracy: 0.9333 - 179ms/epoch - 9ms/step  
## Epoch 47/200  
## 21/21 - 0s - loss: 0.2227 - accuracy: 0.9429 - val\_loss: 0.2510 - val\_accuracy: 0.9556 - 178ms/epoch - 8ms/step  
## Epoch 48/200  
## 21/21 - 0s - loss: 0.2172 - accuracy: 0.9429 - val\_loss: 0.2454 - val\_accuracy: 0.9556 - 164ms/epoch - 8ms/step  
## Epoch 49/200  
## 21/21 - 0s - loss: 0.2126 - accuracy: 0.9429 - val\_loss: 0.2400 - val\_accuracy: 0.9556 - 171ms/epoch - 8ms/step  
## Epoch 50/200  
## 21/21 - 0s - loss: 0.2060 - accuracy: 0.9333 - val\_loss: 0.2347 - val\_accuracy: 0.9556 - 152ms/epoch - 7ms/step  
## Epoch 51/200  
## 21/21 - 0s - loss: 0.2018 - accuracy: 0.9429 - val\_loss: 0.2299 - val\_accuracy: 0.9556 - 173ms/epoch - 8ms/step  
## Epoch 52/200  
## 21/21 - 0s - loss: 0.1957 - accuracy: 0.9429 - val\_loss: 0.2252 - val\_accuracy: 0.9556 - 164ms/epoch - 8ms/step  
## Epoch 53/200  
## 21/21 - 0s - loss: 0.1936 - accuracy: 0.9524 - val\_loss: 0.2210 - val\_accuracy: 0.9556 - 201ms/epoch - 10ms/step  
## Epoch 54/200  
## 21/21 - 0s - loss: 0.1871 - accuracy: 0.9333 - val\_loss: 0.2168 - val\_accuracy: 0.9556 - 173ms/epoch - 8ms/step  
## Epoch 55/200  
## 21/21 - 0s - loss: 0.1838 - accuracy: 0.9429 - val\_loss: 0.2128 - val\_accuracy: 0.9556 - 171ms/epoch - 8ms/step  
## Epoch 56/200  
## 21/21 - 0s - loss: 0.1820 - accuracy: 0.9333 - val\_loss: 0.2093 - val\_accuracy: 0.9333 - 165ms/epoch - 8ms/step  
## Epoch 57/200  
## 21/21 - 0s - loss: 0.1761 - accuracy: 0.9429 - val\_loss: 0.2049 - val\_accuracy: 0.9556 - 173ms/epoch - 8ms/step  
## Epoch 58/200  
## 21/21 - 0s - loss: 0.1739 - accuracy: 0.9429 - val\_loss: 0.2015 - val\_accuracy: 0.9556 - 183ms/epoch - 9ms/step  
## Epoch 59/200  
## 21/21 - 0s - loss: 0.1683 - accuracy: 0.9333 - val\_loss: 0.1993 - val\_accuracy: 0.9333 - 174ms/epoch - 8ms/step  
## Epoch 60/200  
## 21/21 - 0s - loss: 0.1657 - accuracy: 0.9524 - val\_loss: 0.1953 - val\_accuracy: 0.9556 - 170ms/epoch - 8ms/step  
## Epoch 61/200  
## 21/21 - 0s - loss: 0.1633 - accuracy: 0.9429 - val\_loss: 0.1925 - val\_accuracy: 0.9556 - 166ms/epoch - 8ms/step  
## Epoch 62/200  
## 21/21 - 0s - loss: 0.1667 - accuracy: 0.9429 - val\_loss: 0.1897 - val\_accuracy: 0.9556 - 174ms/epoch - 8ms/step  
## Epoch 63/200  
## 21/21 - 0s - loss: 0.1592 - accuracy: 0.9429 - val\_loss: 0.1881 - val\_accuracy: 0.9333 - 208ms/epoch - 10ms/step  
## Epoch 64/200  
## 21/21 - 0s - loss: 0.1533 - accuracy: 0.9429 - val\_loss: 0.1838 - val\_accuracy: 0.9556 - 169ms/epoch - 8ms/step  
## Epoch 65/200  
## 21/21 - 0s - loss: 0.1563 - accuracy: 0.9429 - val\_loss: 0.1814 - val\_accuracy: 0.9556 - 154ms/epoch - 7ms/step  
## Epoch 66/200  
## 21/21 - 0s - loss: 0.1488 - accuracy: 0.9524 - val\_loss: 0.1812 - val\_accuracy: 0.9333 - 167ms/epoch - 8ms/step  
## Epoch 67/200  
## 21/21 - 0s - loss: 0.1485 - accuracy: 0.9524 - val\_loss: 0.1770 - val\_accuracy: 0.9556 - 171ms/epoch - 8ms/step  
## Epoch 68/200  
## 21/21 - 0s - loss: 0.1467 - accuracy: 0.9429 - val\_loss: 0.1748 - val\_accuracy: 0.9556 - 162ms/epoch - 8ms/step  
## Epoch 69/200  
## 21/21 - 0s - loss: 0.1433 - accuracy: 0.9524 - val\_loss: 0.1721 - val\_accuracy: 0.9556 - 170ms/epoch - 8ms/step  
## Epoch 70/200  
## 21/21 - 0s - loss: 0.1415 - accuracy: 0.9429 - val\_loss: 0.1704 - val\_accuracy: 0.9556 - 168ms/epoch - 8ms/step  
## Epoch 71/200  
## 21/21 - 0s - loss: 0.1400 - accuracy: 0.9524 - val\_loss: 0.1683 - val\_accuracy: 0.9556 - 170ms/epoch - 8ms/step  
## Epoch 72/200  
## 21/21 - 0s - loss: 0.1475 - accuracy: 0.9524 - val\_loss: 0.1670 - val\_accuracy: 0.9556 - 171ms/epoch - 8ms/step  
## Epoch 73/200  
## 21/21 - 0s - loss: 0.1372 - accuracy: 0.9429 - val\_loss: 0.1645 - val\_accuracy: 0.9556 - 179ms/epoch - 9ms/step  
## Epoch 74/200  
## 21/21 - 0s - loss: 0.1335 - accuracy: 0.9524 - val\_loss: 0.1636 - val\_accuracy: 0.9556 - 169ms/epoch - 8ms/step  
## Epoch 75/200  
## 21/21 - 0s - loss: 0.1329 - accuracy: 0.9429 - val\_loss: 0.1624 - val\_accuracy: 0.9556 - 182ms/epoch - 9ms/step  
## Epoch 76/200  
## 21/21 - 0s - loss: 0.1319 - accuracy: 0.9429 - val\_loss: 0.1605 - val\_accuracy: 0.9556 - 171ms/epoch - 8ms/step  
## Epoch 77/200  
## 21/21 - 0s - loss: 0.1316 - accuracy: 0.9429 - val\_loss: 0.1578 - val\_accuracy: 0.9556 - 171ms/epoch - 8ms/step  
## Epoch 78/200  
## 21/21 - 0s - loss: 0.1283 - accuracy: 0.9429 - val\_loss: 0.1602 - val\_accuracy: 0.9333 - 198ms/epoch - 9ms/step  
## Epoch 79/200  
## 21/21 - 0s - loss: 0.1266 - accuracy: 0.9429 - val\_loss: 0.1550 - val\_accuracy: 0.9556 - 201ms/epoch - 10ms/step  
## Epoch 80/200  
## 21/21 - 0s - loss: 0.1298 - accuracy: 0.9429 - val\_loss: 0.1566 - val\_accuracy: 0.9333 - 170ms/epoch - 8ms/step  
## Epoch 81/200  
## 21/21 - 0s - loss: 0.1235 - accuracy: 0.9524 - val\_loss: 0.1520 - val\_accuracy: 0.9556 - 177ms/epoch - 8ms/step  
## Epoch 82/200  
## 21/21 - 0s - loss: 0.1233 - accuracy: 0.9429 - val\_loss: 0.1515 - val\_accuracy: 0.9556 - 151ms/epoch - 7ms/step  
## Epoch 83/200  
## 21/21 - 0s - loss: 0.1216 - accuracy: 0.9429 - val\_loss: 0.1504 - val\_accuracy: 0.9556 - 172ms/epoch - 8ms/step  
## Epoch 84/200  
## 21/21 - 0s - loss: 0.1212 - accuracy: 0.9524 - val\_loss: 0.1489 - val\_accuracy: 0.9556 - 167ms/epoch - 8ms/step  
## Epoch 85/200  
## 21/21 - 0s - loss: 0.1194 - accuracy: 0.9429 - val\_loss: 0.1469 - val\_accuracy: 0.9556 - 169ms/epoch - 8ms/step  
## Epoch 86/200  
## 21/21 - 0s - loss: 0.1169 - accuracy: 0.9524 - val\_loss: 0.1485 - val\_accuracy: 0.9333 - 176ms/epoch - 8ms/step  
## Epoch 87/200  
## 21/21 - 0s - loss: 0.1171 - accuracy: 0.9619 - val\_loss: 0.1482 - val\_accuracy: 0.9333 - 176ms/epoch - 8ms/step  
## Epoch 88/200  
## 21/21 - 0s - loss: 0.1146 - accuracy: 0.9429 - val\_loss: 0.1445 - val\_accuracy: 0.9556 - 179ms/epoch - 9ms/step  
## Epoch 89/200  
## 21/21 - 0s - loss: 0.1150 - accuracy: 0.9524 - val\_loss: 0.1424 - val\_accuracy: 0.9556 - 165ms/epoch - 8ms/step  
## Epoch 90/200  
## 21/21 - 0s - loss: 0.1146 - accuracy: 0.9524 - val\_loss: 0.1416 - val\_accuracy: 0.9556 - 164ms/epoch - 8ms/step  
## Epoch 91/200  
## 21/21 - 0s - loss: 0.1138 - accuracy: 0.9524 - val\_loss: 0.1414 - val\_accuracy: 0.9556 - 165ms/epoch - 8ms/step  
## Epoch 92/200  
## 21/21 - 0s - loss: 0.1121 - accuracy: 0.9524 - val\_loss: 0.1417 - val\_accuracy: 0.9556 - 185ms/epoch - 9ms/step  
## Epoch 93/200  
## 21/21 - 0s - loss: 0.1120 - accuracy: 0.9429 - val\_loss: 0.1389 - val\_accuracy: 0.9556 - 165ms/epoch - 8ms/step  
## Epoch 94/200  
## 21/21 - 0s - loss: 0.1103 - accuracy: 0.9524 - val\_loss: 0.1380 - val\_accuracy: 0.9556 - 178ms/epoch - 8ms/step  
## Epoch 95/200  
## 21/21 - 0s - loss: 0.1079 - accuracy: 0.9524 - val\_loss: 0.1390 - val\_accuracy: 0.9556 - 170ms/epoch - 8ms/step  
## Epoch 96/200  
## 21/21 - 0s - loss: 0.1083 - accuracy: 0.9429 - val\_loss: 0.1387 - val\_accuracy: 0.9333 - 165ms/epoch - 8ms/step  
## Epoch 97/200  
## 21/21 - 0s - loss: 0.1167 - accuracy: 0.9429 - val\_loss: 0.1348 - val\_accuracy: 0.9778 - 173ms/epoch - 8ms/step  
## Epoch 98/200  
## 21/21 - 0s - loss: 0.1112 - accuracy: 0.9429 - val\_loss: 0.1378 - val\_accuracy: 0.9333 - 186ms/epoch - 9ms/step  
## Epoch 99/200  
## 21/21 - 0s - loss: 0.1064 - accuracy: 0.9429 - val\_loss: 0.1346 - val\_accuracy: 0.9556 - 171ms/epoch - 8ms/step  
## Epoch 100/200  
## 21/21 - 0s - loss: 0.1047 - accuracy: 0.9524 - val\_loss: 0.1337 - val\_accuracy: 0.9556 - 178ms/epoch - 8ms/step  
## Epoch 101/200  
## 21/21 - 0s - loss: 0.1074 - accuracy: 0.9524 - val\_loss: 0.1335 - val\_accuracy: 0.9556 - 163ms/epoch - 8ms/step  
## Epoch 102/200  
## 21/21 - 0s - loss: 0.1040 - accuracy: 0.9429 - val\_loss: 0.1338 - val\_accuracy: 0.9333 - 176ms/epoch - 8ms/step  
## Epoch 103/200  
## 21/21 - 0s - loss: 0.1039 - accuracy: 0.9619 - val\_loss: 0.1315 - val\_accuracy: 0.9556 - 179ms/epoch - 9ms/step  
## Epoch 104/200  
## 21/21 - 0s - loss: 0.1093 - accuracy: 0.9524 - val\_loss: 0.1303 - val\_accuracy: 0.9556 - 164ms/epoch - 8ms/step  
## Epoch 105/200  
## 21/21 - 0s - loss: 0.1011 - accuracy: 0.9524 - val\_loss: 0.1337 - val\_accuracy: 0.9333 - 163ms/epoch - 8ms/step  
## Epoch 106/200  
## 21/21 - 0s - loss: 0.1034 - accuracy: 0.9524 - val\_loss: 0.1287 - val\_accuracy: 0.9556 - 165ms/epoch - 8ms/step  
## Epoch 107/200  
## 21/21 - 0s - loss: 0.1043 - accuracy: 0.9524 - val\_loss: 0.1303 - val\_accuracy: 0.9556 - 172ms/epoch - 8ms/step  
## Epoch 108/200  
## 21/21 - 0s - loss: 0.0992 - accuracy: 0.9524 - val\_loss: 0.1270 - val\_accuracy: 0.9556 - 167ms/epoch - 8ms/step  
## Epoch 109/200  
## 21/21 - 0s - loss: 0.0997 - accuracy: 0.9524 - val\_loss: 0.1274 - val\_accuracy: 0.9556 - 216ms/epoch - 10ms/step  
## Epoch 110/200  
## 21/21 - 0s - loss: 0.0993 - accuracy: 0.9524 - val\_loss: 0.1277 - val\_accuracy: 0.9556 - 171ms/epoch - 8ms/step  
## Epoch 111/200  
## 21/21 - 0s - loss: 0.0995 - accuracy: 0.9429 - val\_loss: 0.1259 - val\_accuracy: 0.9556 - 159ms/epoch - 8ms/step  
## Epoch 112/200  
## 21/21 - 0s - loss: 0.0985 - accuracy: 0.9524 - val\_loss: 0.1254 - val\_accuracy: 0.9556 - 171ms/epoch - 8ms/step  
## Epoch 113/200  
## 21/21 - 0s - loss: 0.1021 - accuracy: 0.9429 - val\_loss: 0.1250 - val\_accuracy: 0.9556 - 172ms/epoch - 8ms/step  
## Epoch 114/200  
## 21/21 - 0s - loss: 0.0965 - accuracy: 0.9524 - val\_loss: 0.1237 - val\_accuracy: 0.9556 - 163ms/epoch - 8ms/step  
## Epoch 115/200  
## 21/21 - 0s - loss: 0.0993 - accuracy: 0.9429 - val\_loss: 0.1239 - val\_accuracy: 0.9556 - 170ms/epoch - 8ms/step  
## Epoch 116/200  
## 21/21 - 0s - loss: 0.0999 - accuracy: 0.9524 - val\_loss: 0.1222 - val\_accuracy: 0.9556 - 176ms/epoch - 8ms/step  
## Epoch 117/200  
## 21/21 - 0s - loss: 0.0980 - accuracy: 0.9524 - val\_loss: 0.1253 - val\_accuracy: 0.9333 - 191ms/epoch - 9ms/step  
## Epoch 118/200  
## 21/21 - 0s - loss: 0.0936 - accuracy: 0.9524 - val\_loss: 0.1219 - val\_accuracy: 0.9556 - 174ms/epoch - 8ms/step  
## Epoch 119/200  
## 21/21 - 0s - loss: 0.0942 - accuracy: 0.9524 - val\_loss: 0.1216 - val\_accuracy: 0.9556 - 162ms/epoch - 8ms/step  
## Epoch 120/200  
## 21/21 - 0s - loss: 0.0938 - accuracy: 0.9524 - val\_loss: 0.1205 - val\_accuracy: 0.9556 - 162ms/epoch - 8ms/step  
## Epoch 121/200  
## 21/21 - 0s - loss: 0.0934 - accuracy: 0.9524 - val\_loss: 0.1207 - val\_accuracy: 0.9556 - 166ms/epoch - 8ms/step  
## Epoch 122/200  
## 21/21 - 0s - loss: 0.0934 - accuracy: 0.9524 - val\_loss: 0.1205 - val\_accuracy: 0.9556 - 156ms/epoch - 7ms/step  
## Epoch 123/200  
## 21/21 - 0s - loss: 0.0923 - accuracy: 0.9524 - val\_loss: 0.1199 - val\_accuracy: 0.9556 - 282ms/epoch - 13ms/step  
## Epoch 124/200  
## 21/21 - 0s - loss: 0.0929 - accuracy: 0.9524 - val\_loss: 0.1213 - val\_accuracy: 0.9556 - 187ms/epoch - 9ms/step  
## Epoch 125/200  
## 21/21 - 0s - loss: 0.0930 - accuracy: 0.9524 - val\_loss: 0.1175 - val\_accuracy: 0.9778 - 166ms/epoch - 8ms/step  
## Epoch 126/200  
## 21/21 - 0s - loss: 0.0918 - accuracy: 0.9524 - val\_loss: 0.1178 - val\_accuracy: 0.9556 - 165ms/epoch - 8ms/step  
## Epoch 127/200  
## 21/21 - 0s - loss: 0.0951 - accuracy: 0.9429 - val\_loss: 0.1208 - val\_accuracy: 0.9333 - 195ms/epoch - 9ms/step  
## Epoch 128/200  
## 21/21 - 0s - loss: 0.0970 - accuracy: 0.9524 - val\_loss: 0.1160 - val\_accuracy: 0.9778 - 164ms/epoch - 8ms/step  
## Epoch 129/200  
## 21/21 - 0s - loss: 0.0906 - accuracy: 0.9524 - val\_loss: 0.1174 - val\_accuracy: 0.9556 - 166ms/epoch - 8ms/step  
## Epoch 130/200  
## 21/21 - 0s - loss: 0.0900 - accuracy: 0.9524 - val\_loss: 0.1193 - val\_accuracy: 0.9556 - 158ms/epoch - 8ms/step  
## Epoch 131/200  
## 21/21 - 0s - loss: 0.0904 - accuracy: 0.9524 - val\_loss: 0.1202 - val\_accuracy: 0.9333 - 172ms/epoch - 8ms/step  
## Epoch 132/200  
## 21/21 - 0s - loss: 0.0885 - accuracy: 0.9524 - val\_loss: 0.1159 - val\_accuracy: 0.9556 - 165ms/epoch - 8ms/step  
## Epoch 133/200  
## 21/21 - 0s - loss: 0.0914 - accuracy: 0.9524 - val\_loss: 0.1135 - val\_accuracy: 0.9778 - 166ms/epoch - 8ms/step  
## Epoch 134/200  
## 21/21 - 0s - loss: 0.0892 - accuracy: 0.9524 - val\_loss: 0.1163 - val\_accuracy: 0.9556 - 162ms/epoch - 8ms/step  
## Epoch 135/200  
## 21/21 - 0s - loss: 0.0887 - accuracy: 0.9524 - val\_loss: 0.1143 - val\_accuracy: 0.9556 - 170ms/epoch - 8ms/step  
## Epoch 136/200  
## 21/21 - 0s - loss: 0.0872 - accuracy: 0.9524 - val\_loss: 0.1152 - val\_accuracy: 0.9556 - 166ms/epoch - 8ms/step  
## Epoch 137/200  
## 21/21 - 0s - loss: 0.0905 - accuracy: 0.9524 - val\_loss: 0.1129 - val\_accuracy: 0.9778 - 178ms/epoch - 8ms/step  
## Epoch 138/200  
## 21/21 - 0s - loss: 0.0882 - accuracy: 0.9524 - val\_loss: 0.1133 - val\_accuracy: 0.9556 - 172ms/epoch - 8ms/step  
## Epoch 139/200  
## 21/21 - 0s - loss: 0.0880 - accuracy: 0.9524 - val\_loss: 0.1162 - val\_accuracy: 0.9333 - 173ms/epoch - 8ms/step  
## Epoch 140/200  
## 21/21 - 0s - loss: 0.0872 - accuracy: 0.9524 - val\_loss: 0.1125 - val\_accuracy: 0.9556 - 161ms/epoch - 8ms/step  
## Epoch 141/200  
## 21/21 - 0s - loss: 0.0899 - accuracy: 0.9524 - val\_loss: 0.1173 - val\_accuracy: 0.9333 - 187ms/epoch - 9ms/step  
## Epoch 142/200  
## 21/21 - 0s - loss: 0.0864 - accuracy: 0.9524 - val\_loss: 0.1115 - val\_accuracy: 0.9556 - 146ms/epoch - 7ms/step  
## Epoch 143/200  
## 21/21 - 0s - loss: 0.0867 - accuracy: 0.9524 - val\_loss: 0.1107 - val\_accuracy: 0.9778 - 166ms/epoch - 8ms/step  
## Epoch 144/200  
## 21/21 - 0s - loss: 0.0859 - accuracy: 0.9524 - val\_loss: 0.1109 - val\_accuracy: 0.9556 - 169ms/epoch - 8ms/step  
## Epoch 145/200  
## 21/21 - 0s - loss: 0.0854 - accuracy: 0.9524 - val\_loss: 0.1125 - val\_accuracy: 0.9556 - 170ms/epoch - 8ms/step  
## Epoch 146/200  
## 21/21 - 0s - loss: 0.0849 - accuracy: 0.9524 - val\_loss: 0.1105 - val\_accuracy: 0.9556 - 164ms/epoch - 8ms/step  
## Epoch 147/200  
## 21/21 - 0s - loss: 0.0913 - accuracy: 0.9429 - val\_loss: 0.1120 - val\_accuracy: 0.9556 - 202ms/epoch - 10ms/step  
## Epoch 148/200  
## 21/21 - 0s - loss: 0.0863 - accuracy: 0.9524 - val\_loss: 0.1078 - val\_accuracy: 0.9778 - 200ms/epoch - 10ms/step  
## Epoch 149/200  
## 21/21 - 0s - loss: 0.0871 - accuracy: 0.9524 - val\_loss: 0.1099 - val\_accuracy: 0.9556 - 169ms/epoch - 8ms/step  
## Epoch 150/200  
## 21/21 - 0s - loss: 0.0848 - accuracy: 0.9524 - val\_loss: 0.1075 - val\_accuracy: 0.9778 - 166ms/epoch - 8ms/step  
## Epoch 151/200  
## 21/21 - 0s - loss: 0.0833 - accuracy: 0.9524 - val\_loss: 0.1096 - val\_accuracy: 0.9556 - 172ms/epoch - 8ms/step  
## Epoch 152/200  
## 21/21 - 0s - loss: 0.0867 - accuracy: 0.9524 - val\_loss: 0.1093 - val\_accuracy: 0.9556 - 171ms/epoch - 8ms/step  
## Epoch 153/200  
## 21/21 - 0s - loss: 0.0879 - accuracy: 0.9524 - val\_loss: 0.1059 - val\_accuracy: 0.9778 - 163ms/epoch - 8ms/step  
## Epoch 154/200  
## 21/21 - 0s - loss: 0.0821 - accuracy: 0.9524 - val\_loss: 0.1087 - val\_accuracy: 0.9556 - 211ms/epoch - 10ms/step  
## Epoch 155/200  
## 21/21 - 0s - loss: 0.0823 - accuracy: 0.9524 - val\_loss: 0.1095 - val\_accuracy: 0.9556 - 180ms/epoch - 9ms/step  
## Epoch 156/200  
## 21/21 - 0s - loss: 0.0826 - accuracy: 0.9524 - val\_loss: 0.1078 - val\_accuracy: 0.9556 - 179ms/epoch - 9ms/step  
## Epoch 157/200  
## 21/21 - 0s - loss: 0.0868 - accuracy: 0.9524 - val\_loss: 0.1072 - val\_accuracy: 0.9556 - 174ms/epoch - 8ms/step  
## Epoch 158/200  
## 21/21 - 0s - loss: 0.0846 - accuracy: 0.9524 - val\_loss: 0.1071 - val\_accuracy: 0.9556 - 160ms/epoch - 8ms/step  
## Epoch 159/200  
## 21/21 - 0s - loss: 0.0827 - accuracy: 0.9524 - val\_loss: 0.1075 - val\_accuracy: 0.9556 - 165ms/epoch - 8ms/step  
## Epoch 160/200  
## 21/21 - 0s - loss: 0.0810 - accuracy: 0.9524 - val\_loss: 0.1047 - val\_accuracy: 0.9778 - 166ms/epoch - 8ms/step  
## Epoch 161/200  
## 21/21 - 0s - loss: 0.0836 - accuracy: 0.9524 - val\_loss: 0.1040 - val\_accuracy: 0.9778 - 166ms/epoch - 8ms/step  
## Epoch 162/200  
## 21/21 - 0s - loss: 0.0815 - accuracy: 0.9524 - val\_loss: 0.1047 - val\_accuracy: 0.9778 - 169ms/epoch - 8ms/step  
## Epoch 163/200  
## 21/21 - 0s - loss: 0.0819 - accuracy: 0.9524 - val\_loss: 0.1056 - val\_accuracy: 0.9556 - 161ms/epoch - 8ms/step  
## Epoch 164/200  
## 21/21 - 0s - loss: 0.0823 - accuracy: 0.9524 - val\_loss: 0.1051 - val\_accuracy: 0.9778 - 160ms/epoch - 8ms/step  
## Epoch 165/200  
## 21/21 - 0s - loss: 0.0822 - accuracy: 0.9524 - val\_loss: 0.1022 - val\_accuracy: 0.9778 - 169ms/epoch - 8ms/step  
## Epoch 166/200  
## 21/21 - 0s - loss: 0.0807 - accuracy: 0.9524 - val\_loss: 0.1072 - val\_accuracy: 0.9556 - 159ms/epoch - 8ms/step  
## Epoch 167/200  
## 21/21 - 0s - loss: 0.0828 - accuracy: 0.9524 - val\_loss: 0.1034 - val\_accuracy: 0.9778 - 158ms/epoch - 8ms/step  
## Epoch 168/200  
## 21/21 - 0s - loss: 0.0798 - accuracy: 0.9524 - val\_loss: 0.1028 - val\_accuracy: 0.9778 - 159ms/epoch - 8ms/step  
## Epoch 169/200  
## 21/21 - 0s - loss: 0.0822 - accuracy: 0.9524 - val\_loss: 0.1046 - val\_accuracy: 0.9556 - 199ms/epoch - 9ms/step  
## Epoch 170/200  
## 21/21 - 0s - loss: 0.0805 - accuracy: 0.9524 - val\_loss: 0.1022 - val\_accuracy: 0.9778 - 165ms/epoch - 8ms/step  
## Epoch 171/200  
## 21/21 - 0s - loss: 0.0792 - accuracy: 0.9524 - val\_loss: 0.1032 - val\_accuracy: 0.9778 - 178ms/epoch - 8ms/step  
## Epoch 172/200  
## 21/21 - 0s - loss: 0.0800 - accuracy: 0.9524 - val\_loss: 0.1051 - val\_accuracy: 0.9556 - 166ms/epoch - 8ms/step  
## Epoch 173/200  
## 21/21 - 0s - loss: 0.0812 - accuracy: 0.9524 - val\_loss: 0.1010 - val\_accuracy: 0.9778 - 167ms/epoch - 8ms/step  
## Epoch 174/200  
## 21/21 - 0s - loss: 0.0794 - accuracy: 0.9524 - val\_loss: 0.1054 - val\_accuracy: 0.9556 - 171ms/epoch - 8ms/step  
## Epoch 175/200  
## 21/21 - 0s - loss: 0.0801 - accuracy: 0.9524 - val\_loss: 0.1037 - val\_accuracy: 0.9556 - 164ms/epoch - 8ms/step  
## Epoch 176/200  
## 21/21 - 0s - loss: 0.0799 - accuracy: 0.9524 - val\_loss: 0.0994 - val\_accuracy: 0.9778 - 167ms/epoch - 8ms/step  
## Epoch 177/200  
## 21/21 - 0s - loss: 0.0781 - accuracy: 0.9524 - val\_loss: 0.1022 - val\_accuracy: 0.9778 - 177ms/epoch - 8ms/step  
## Epoch 178/200  
## 21/21 - 0s - loss: 0.0791 - accuracy: 0.9524 - val\_loss: 0.1038 - val\_accuracy: 0.9556 - 164ms/epoch - 8ms/step  
## Epoch 179/200  
## 21/21 - 0s - loss: 0.0807 - accuracy: 0.9524 - val\_loss: 0.1000 - val\_accuracy: 0.9778 - 161ms/epoch - 8ms/step  
## Epoch 180/200  
## 21/21 - 0s - loss: 0.0795 - accuracy: 0.9524 - val\_loss: 0.0998 - val\_accuracy: 0.9778 - 167ms/epoch - 8ms/step  
## Epoch 181/200  
## 21/21 - 0s - loss: 0.0797 - accuracy: 0.9524 - val\_loss: 0.1029 - val\_accuracy: 0.9556 - 160ms/epoch - 8ms/step  
## Epoch 182/200  
## 21/21 - 0s - loss: 0.0844 - accuracy: 0.9524 - val\_loss: 0.1012 - val\_accuracy: 0.9778 - 159ms/epoch - 8ms/step  
## Epoch 183/200  
## 21/21 - 0s - loss: 0.0780 - accuracy: 0.9524 - val\_loss: 0.1006 - val\_accuracy: 0.9778 - 164ms/epoch - 8ms/step  
## Epoch 184/200  
## 21/21 - 0s - loss: 0.0772 - accuracy: 0.9524 - val\_loss: 0.0993 - val\_accuracy: 0.9778 - 175ms/epoch - 8ms/step  
## Epoch 185/200  
## 21/21 - 0s - loss: 0.0775 - accuracy: 0.9524 - val\_loss: 0.0991 - val\_accuracy: 0.9778 - 195ms/epoch - 9ms/step  
## Epoch 186/200  
## 21/21 - 0s - loss: 0.0773 - accuracy: 0.9524 - val\_loss: 0.0987 - val\_accuracy: 0.9778 - 150ms/epoch - 7ms/step  
## Epoch 187/200  
## 21/21 - 0s - loss: 0.0803 - accuracy: 0.9524 - val\_loss: 0.0989 - val\_accuracy: 0.9778 - 161ms/epoch - 8ms/step  
## Epoch 188/200  
## 21/21 - 0s - loss: 0.0775 - accuracy: 0.9524 - val\_loss: 0.1014 - val\_accuracy: 0.9556 - 163ms/epoch - 8ms/step  
## Epoch 189/200  
## 21/21 - 0s - loss: 0.0766 - accuracy: 0.9524 - val\_loss: 0.0985 - val\_accuracy: 0.9778 - 165ms/epoch - 8ms/step  
## Epoch 190/200  
## 21/21 - 0s - loss: 0.0764 - accuracy: 0.9524 - val\_loss: 0.0979 - val\_accuracy: 0.9778 - 169ms/epoch - 8ms/step  
## Epoch 191/200  
## 21/21 - 0s - loss: 0.0765 - accuracy: 0.9524 - val\_loss: 0.0975 - val\_accuracy: 0.9778 - 158ms/epoch - 8ms/step  
## Epoch 192/200  
## 21/21 - 0s - loss: 0.0779 - accuracy: 0.9524 - val\_loss: 0.0991 - val\_accuracy: 0.9778 - 149ms/epoch - 7ms/step  
## Epoch 193/200  
## 21/21 - 0s - loss: 0.0758 - accuracy: 0.9524 - val\_loss: 0.0967 - val\_accuracy: 0.9778 - 161ms/epoch - 8ms/step  
## Epoch 194/200  
## 21/21 - 0s - loss: 0.0764 - accuracy: 0.9524 - val\_loss: 0.0972 - val\_accuracy: 0.9778 - 171ms/epoch - 8ms/step  
## Epoch 195/200  
## 21/21 - 0s - loss: 0.0763 - accuracy: 0.9524 - val\_loss: 0.1006 - val\_accuracy: 0.9556 - 163ms/epoch - 8ms/step  
## Epoch 196/200  
## 21/21 - 0s - loss: 0.0799 - accuracy: 0.9524 - val\_loss: 0.0986 - val\_accuracy: 0.9778 - 167ms/epoch - 8ms/step  
## Epoch 197/200  
## 21/21 - 0s - loss: 0.0756 - accuracy: 0.9524 - val\_loss: 0.0948 - val\_accuracy: 0.9778 - 160ms/epoch - 8ms/step  
## Epoch 198/200  
## 21/21 - 0s - loss: 0.0790 - accuracy: 0.9524 - val\_loss: 0.0994 - val\_accuracy: 0.9556 - 162ms/epoch - 8ms/step  
## Epoch 199/200  
## 21/21 - 0s - loss: 0.0757 - accuracy: 0.9524 - val\_loss: 0.0951 - val\_accuracy: 0.9778 - 160ms/epoch - 8ms/step  
## Epoch 200/200  
## 21/21 - 0s - loss: 0.0799 - accuracy: 0.9524 - val\_loss: 0.0942 - val\_accuracy: 0.9778 - 166ms/epoch - 8ms/step

# **6.Evaluate performance**

score <- model %>% evaluate(x, y) #Evaluate the model on the dataset

## 5/5 - 0s - loss: 0.0808 - accuracy: 0.9600 - 375ms/epoch - 75ms/step

cat("Test accuracy:", score["accuracy"], "\n") #Print the test accuracy

## Test accuracy: 0.96

# **7. Graphics**

# Plot training history  
plot(fit)

