Assignment 2

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2023-03-26

```
library(reticulate)
use_condaenv('r-reticulate')
library(tensorflow)
library(keras)
```

```
original_dataset_dir <- "~/Downloads/dogs-vs-cats"

base_dir <- "~/Downloads/cats_and_dogs_small"
dir.create(base_dir)
```

```
## Warning in dir.create(base_dir):
## '/Users/jacobfabian/Downloads/cats_and_dogs_small' already exists
```

```
train_dir <- file.path(base_dir, "train")
dir.create(train_dir)
```

```
## Warning in dir.create(train_dir):
## '/Users/jacobfabian/Downloads/cats_and_dogs_small/train' already exists
```

```
validation_dir <- file.path(base_dir, "validation")
dir.create(validation_dir)
```

```
## Warning in dir.create(validation_dir):
## '/Users/jacobfabian/Downloads/cats_and_dogs_small/validation' already exists
```

```
test_dir <- file.path(base_dir, "test")
dir.create(test_dir)
```

```
## Warning in dir.create(test_dir):
## '/Users/jacobfabian/Downloads/cats_and_dogs_small/test' already exists
```

```
train_cats_dir <- file.path(train_dir, "cats")
dir.create(train_cats_dir)
```

```
## Warning in dir.create(train_cats_dir):
## '/Users/jacobfabian/Downloads/cats_and_dogs_small/train/cats' already exists
```

```r
train_dogs_dir <- file.path(train_dir, "dogs")
dir.create(train_dogs_dir)
```

```
## Warning in dir.create(train_dogs_dir):
## ’/Users/jacobfabian/Downloads/cats_and_dogs_small/train/dogs’ already exists
```

```r
validation_cats_dir <- file.path(validation_dir, "cats")
dir.create(validation_cats_dir)
```

```
## Warning in dir.create(validation_cats_dir):
## ’/Users/jacobfabian/Downloads/cats_and_dogs_small/validation/cats’ already
## exists
```

```r
validation_dogs_dir <- file.path(validation_dir, "dogs")
dir.create(validation_dogs_dir)
```

```
## Warning in dir.create(validation_dogs_dir):
## ’/Users/jacobfabian/Downloads/cats_and_dogs_small/validation/dogs’ already
## exists
```

```r
test_cats_dir <- file.path(test_dir, "cats")
dir.create(test_cats_dir)
```

```
## Warning in dir.create(test_cats_dir):
## ’/Users/jacobfabian/Downloads/cats_and_dogs_small/test/cats’ already exists
```

```r
test_dogs_dir <- file.path(test_dir, "dogs")
dir.create(test_dogs_dir)
```

```
## Warning in dir.create(test_dogs_dir):
## ’/Users/jacobfabian/Downloads/cats_and_dogs_small/test/dogs’ already exists
```

```r
fnames <- paste0("cat.", 1:1000, ".jpg")
file.copy(file.path(original_dataset_dir, fnames),
          file.path(train_cats_dir))

fnames <- paste0("cat.", 1001:1500, ".jpg")
file.copy(file.path(original_dataset_dir, fnames),
          file.path(validation_cats_dir))

fnames <- paste0("cat.", 1501:2000, ".jpg")
file.copy(file.path(original_dataset_dir, fnames),
          file.path(test_cats_dir))

fnames <- paste0("dog.", 1:1000, ".jpg")
file.copy(file.path(original_dataset_dir, fnames),
          file.path(train_dogs_dir))

fnames <- paste0("dog.", 1001:1500, ".jpg")
```

```
file.copy(file.path(original_dataset_dir, fnames),
          file.path(validation_dogs_dir))

fnames <- paste0("dog.", 1501:2000, ".jpg")
file.copy(file.path(original_dataset_dir, fnames),
          file.path(test_dogs_dir))
```

```
library(keras)
library(tensorflow)

model <- keras_model_sequential() %>%
  layer_conv_2d(filters = 32, kernel_size = c(3, 3), activation = "relu",
                input_shape = c(150, 150, 3)) %>%
  layer_max_pooling_2d(pool_size = c(2, 2)) %>%
  layer_conv_2d(filters = 64, kernel_size = c(3, 3), activation = "relu") %>%
  layer_max_pooling_2d(pool_size = c(2, 2)) %>%
  layer_conv_2d(filters = 128, kernel_size = c(3, 3), activation = "relu") %>%
  layer_max_pooling_2d(pool_size = c(2, 2)) %>%
  layer_conv_2d(filters = 128, kernel_size = c(3, 3), activation = "relu") %>%
  layer_max_pooling_2d(pool_size = c(2, 2)) %>%
  layer_flatten() %>%
  layer_dense(units = 512, activation = "relu") %>%
  layer_dense(units = 1, activation = "sigmoid")
```

```
summary(model)
```

```
## Model: "sequential"
## ________________________________________________________________________________
##  Layer (type)                       Output Shape                    Param #
## ================================================================================
##  conv2d_3 (Conv2D)                  (None, 148, 148, 32)            896
##  max_pooling2d_3 (MaxPooling2D)     (None, 74, 74, 32)              0
##  conv2d_2 (Conv2D)                  (None, 72, 72, 64)              18496
##  max_pooling2d_2 (MaxPooling2D)     (None, 36, 36, 64)              0
##  conv2d_1 (Conv2D)                  (None, 34, 34, 128)             73856
##  max_pooling2d_1 (MaxPooling2D)     (None, 17, 17, 128)             0
##  conv2d (Conv2D)                    (None, 15, 15, 128)             147584
##  max_pooling2d (MaxPooling2D)       (None, 7, 7, 128)               0
##  flatten (Flatten)                  (None, 6272)                    0
##  dense_1 (Dense)                    (None, 512)                     3211776
##  dense (Dense)                      (None, 1)                       513
## ================================================================================
## Total params: 3,453,121
## Trainable params: 3,453,121
## Non-trainable params: 0
## ________________________________________________________________________________
```

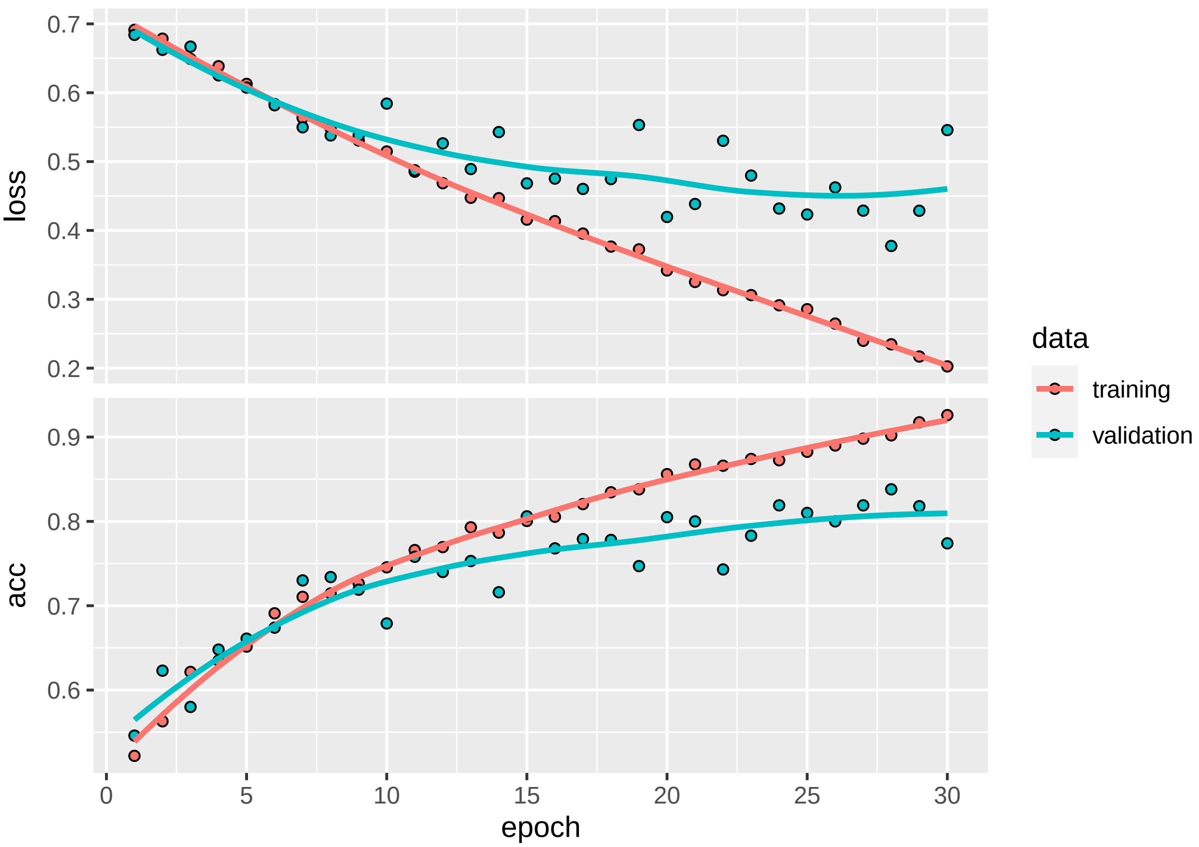
```
model %>% compile(
  loss = "binary_crossentropy",
  optimizer = optimizer_rmsprop(learning_rate = 1e-4),
  metrics = c("acc")
)
```

```
train_datagen <- image_data_generator(rescale = 1/255)
validation_datagen <- image_data_generator(rescale = 1/255)

train_generator <- flow_images_from_directory(
  train_dir,
  train_datagen,
  target_size = c(150, 150),
  batch_size = 20,
  class_mode = "binary"
)

validation_generator <- flow_images_from_directory(
  validation_dir,
  validation_datagen,
  target_size = c(150, 150),
  batch_size = 20,
  class_mode = "binary"
)
```

```
batch<- generator_next(train_generator)
str(batch)
```

```
## List of 2
##  $ : num [1:20, 1:150, 1:150, 1:3] 0.4353 0.0902 0.4314 0.4824 0.1882 ...
##  $ : num [1:20(1d)] 1 0 0 0 1 0 0 1 0 1 ...
```

```
history <- model %>% fit(
  train_generator,
  steps_per_epoch = 100,
  epochs = 30,
  validation_data = validation_generator,
  validation_steps = 50
)
plot(history)
```

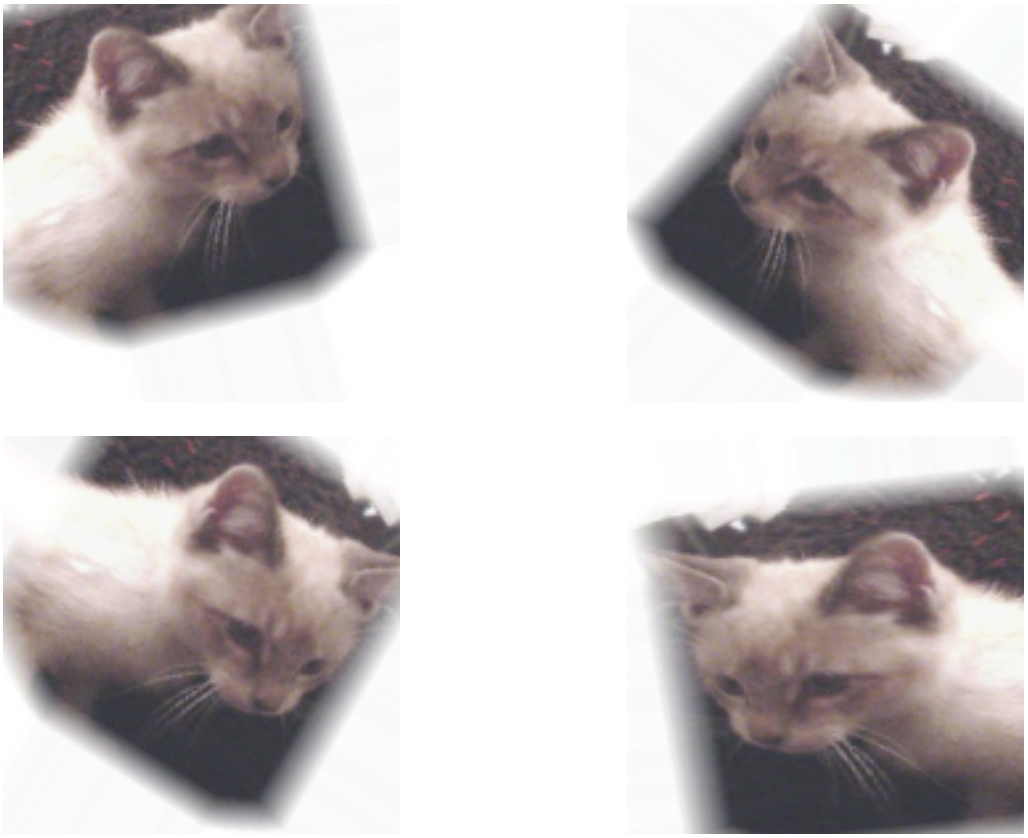


Our first model is highly overfitted. We will try to increase accuracy and reduce overfitting.

Question 1:

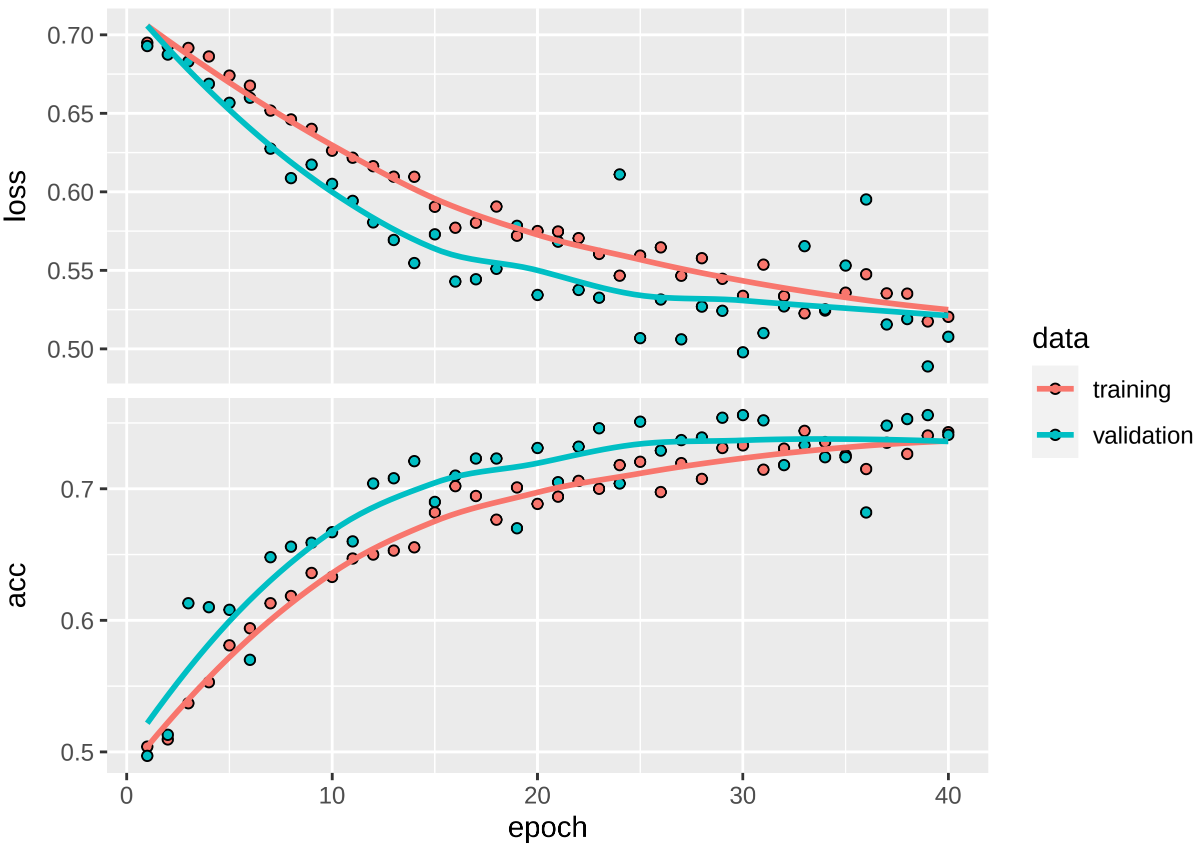
The following code improves upon the base model by adding a dropout layer. This should help the model to stop overfitting to try to improve preformance.

```
datagen <- image_data_generator(
  rescale = 1/255,
  rotation_range = 40,
  width_shift_range = 0.2,
  height_shift_range = 0.2,
  shear_range = 0.2,
  zoom_range = 0.2,
  horizontal_flip = TRUE
)
fnames <- list.files(file.path(train_dir,"cats"), full.names = T)
img_path <- fnames[[round(runif(1,1,length(fnames)))]]
img <- image_load(img_path, target_size = c(150,150))
img_array <- image_to_array(img)
img_array <- array_reshape(img_array, c(1,150,150,3))
augmentation_generator <- flow_images_from_data(
    img_array,
    generator = datagen,
    batch_size = 1
)
op <- par(mfrow=c(2,2), pty="s", mar=c(1,0,.1,0))
for (i in 1:4) {
  batch <- generator_next(augmentation_generator)
  plot(as.raster(batch[1,,,]))
}
```



```
par(op)

model2 <- keras_model_sequential() %>%
  layer_conv_2d(filters = 32, kernel_size = c(3,3), activation = "relu", input_shape = c(150,150,3)) %>
  layer_max_pooling_2d(pool_size = c(2,2)) %>%
  layer_conv_2d(filters = 64, kernel_size = c(3,3), activation = "relu") %>%
  layer_max_pooling_2d(pool_size = c(2,2)) %>%
  layer_conv_2d(filters = 128, kernel_size = c(3,3), activation = "relu") %>%
  layer_max_pooling_2d(pool_size = c(2,2)) %>%
  layer_conv_2d(filters = 128, kernel_size = c(3,3), activation = "relu") %>%
  layer_max_pooling_2d(pool_size = c(2,2)) %>%
  layer_flatten() %>%
  layer_dropout(rate = 0.5) %>%
  layer_dense(units=512, activation = "relu") %>%
  layer_dense(units=1, activation = "sigmoid")
model2 %>% compile(
  loss = "binary_crossentropy",
  optimizer = optimizer_rmsprop(learning_rate = 1e-4),
```

```r
  metrics = c("acc")
)
test_datagen <- image_data_generator(rescale = 1/255)

train_generator <- flow_images_from_directory(
  train_dir,
  datagen,
  target_size = c(150, 150),
  batch_size = 20,
  class_mode = "binary"
)
validation_generator <- flow_images_from_directory(
  validation_dir,
  test_datagen,
  target_size = c(150, 150),
  batch_size = 20,
  class_mode = "binary"
)
history2 <- model2 %>% fit(
  train_generator,
  steps_per_epoch = 100,
  epochs = 40,
  validation_data = validation_generator,
  validation_steps = 50
)
test_datagen <- image_data_generator(rescale = 1/255)

test_generator <- flow_images_from_directory(
  test_dir,
  test_datagen,
  target_size = c(150, 150),
  batch_size = 20,
  class_mode = "binary"
)
plot(history2)
```



```
model2 %>% evaluate_generator(test_generator, steps = 50)
```

```
##      loss       acc
## 0.5156532 0.7480000
```

40 epochs later, the loss is now .508, and the accuracy is now .77

Question 2

Adding more pictures to the training data, while keeping the same number of validation and test images

```
dir.create(base_dir)
train_dir <- file.path(base_dir, "train")
dir.create(train_dir)
validation_dir <- file.path(base_dir, "validation")
dir.create(validation_dir)
test_dir <- file.path(base_dir, "test")
dir.create(test_dir)
train_cats_dir <- file.path(train_dir, "cats")
dir.create(train_cats_dir)
train_dogs_dir <- file.path(train_dir, "dogs")
dir.create(train_dogs_dir)
validation_cats_dir <- file.path(validation_dir, "cats")
```

```
dir.create(validation_cats_dir)
validation_dogs_dir <- file.path(validation_dir, "dogs")
dir.create(validation_dogs_dir)
test_cats_dir <- file.path(test_dir, "cats")
dir.create(test_cats_dir)
test_dogs_dir <- file.path(test_dir, "dogs")
dir.create(test_dogs_dir)
fnames <- paste0("cat.", 1:1500, ".jpg")
file.copy(file.path(original_dataset_dir, fnames),
          file.path(train_cats_dir))
```

```
##    [1] FALSE FALSE FALSE FALSE FALSE FALSE FALSE FALSE FALSE FALSE FALSE FALSE
##   [13] FALSE FALSE FALSE FALSE FALSE FALSE FALSE FALSE FALSE FALSE FALSE FALSE
##   [25] FALSE FALSE FALSE FALSE FALSE FALSE FALSE FALSE FALSE FALSE FALSE FALSE
##   [37] FALSE FALSE FALSE FALSE FALSE FALSE FALSE FALSE FALSE FALSE FALSE FALSE
##   [49] FALSE FALSE FALSE FALSE FALSE FALSE FALSE FALSE FALSE FALSE FALSE FALSE
##   [61] FALSE FALSE FALSE FALSE FALSE FALSE FALSE FALSE FALSE FALSE FALSE FALSE
##   [73] FALSE FALSE FALSE FALSE FALSE FALSE FALSE FALSE FALSE FALSE FALSE FALSE
##   [85] FALSE FALSE FALSE FALSE FALSE FALSE FALSE FALSE FALSE FALSE FALSE FALSE
##   [97] FALSE FALSE FALSE FALSE FALSE FALSE FALSE FALSE FALSE FALSE FALSE FALSE
##  [109] FALSE FALSE FALSE FALSE FALSE FALSE FALSE FALSE FALSE FALSE FALSE FALSE
##  [121] FALSE FALSE FALSE FALSE FALSE FALSE FALSE FALSE FALSE FALSE FALSE FALSE
##  [133] FALSE FALSE FALSE FALSE FALSE FALSE FALSE FALSE FALSE FALSE FALSE FALSE
##  [145] FALSE FALSE FALSE FALSE FALSE FALSE FALSE FALSE FALSE FALSE FALSE FALSE
##  [157] FALSE FALSE FALSE FALSE FALSE FALSE FALSE FALSE FALSE FALSE FALSE FALSE
##  [169] FALSE FALSE FALSE FALSE FALSE FALSE FALSE FALSE FALSE FALSE FALSE FALSE
##  [181] FALSE FALSE FALSE FALSE FALSE FALSE FALSE FALSE FALSE FALSE FALSE FALSE
##  [193] FALSE FALSE FALSE FALSE FALSE FALSE FALSE FALSE FALSE FALSE FALSE FALSE
##  [205] FALSE FALSE FALSE FALSE FALSE FALSE FALSE FALSE FALSE FALSE FALSE FALSE
##  [217] FALSE FALSE FALSE FALSE FALSE FALSE FALSE FALSE FALSE FALSE FALSE FALSE
##  [229] FALSE FALSE FALSE FALSE FALSE FALSE FALSE FALSE FALSE FALSE FALSE FALSE
##  [241] FALSE FALSE FALSE FALSE FALSE FALSE FALSE FALSE FALSE FALSE FALSE FALSE
##  [253] FALSE FALSE FALSE FALSE FALSE FALSE FALSE FALSE FALSE FALSE FALSE FALSE
##  [265] FALSE FALSE FALSE FALSE FALSE FALSE FALSE FALSE FALSE FALSE FALSE FALSE
##  [277] FALSE FALSE FALSE FALSE FALSE FALSE FALSE FALSE FALSE FALSE FALSE FALSE
##  [289] FALSE FALSE FALSE FALSE FALSE FALSE FALSE FALSE FALSE FALSE FALSE FALSE
##  [301] FALSE FALSE FALSE FALSE FALSE FALSE FALSE FALSE FALSE FALSE FALSE FALSE
##  [313] FALSE FALSE FALSE FALSE FALSE FALSE FALSE FALSE FALSE FALSE FALSE FALSE
##  [325] FALSE FALSE FALSE FALSE FALSE FALSE FALSE FALSE FALSE FALSE FALSE FALSE
##  [337] FALSE FALSE FALSE FALSE FALSE FALSE FALSE FALSE FALSE FALSE FALSE FALSE
##  [349] FALSE FALSE FALSE FALSE FALSE FALSE FALSE FALSE FALSE FALSE FALSE FALSE
##  [361] FALSE FALSE FALSE FALSE FALSE FALSE FALSE FALSE FALSE FALSE FALSE FALSE
##  [373] FALSE FALSE FALSE FALSE FALSE FALSE FALSE FALSE FALSE FALSE FALSE FALSE
##  [385] FALSE FALSE FALSE FALSE FALSE FALSE FALSE FALSE FALSE FALSE FALSE FALSE
##  [397] FALSE FALSE FALSE FALSE FALSE FALSE FALSE FALSE FALSE FALSE FALSE FALSE
##  [409] FALSE FALSE FALSE FALSE FALSE FALSE FALSE FALSE FALSE FALSE FALSE FALSE
##  [421] FALSE FALSE FALSE FALSE FALSE FALSE FALSE FALSE FALSE FALSE FALSE FALSE
##  [433] FALSE FALSE FALSE FALSE FALSE FALSE FALSE FALSE FALSE FALSE FALSE FALSE
##  [445] FALSE FALSE FALSE FALSE FALSE FALSE FALSE FALSE FALSE FALSE FALSE FALSE
##  [457] FALSE FALSE FALSE FALSE FALSE FALSE FALSE FALSE FALSE FALSE FALSE FALSE
##  [469] FALSE FALSE FALSE FALSE FALSE FALSE FALSE FALSE FALSE FALSE FALSE FALSE
##  [481] FALSE FALSE FALSE FALSE FALSE FALSE FALSE FALSE FALSE FALSE FALSE FALSE
##  [493] FALSE FALSE FALSE FALSE FALSE FALSE FALSE FALSE FALSE FALSE FALSE FALSE
##  [505] FALSE FALSE FALSE FALSE FALSE FALSE FALSE FALSE FALSE FALSE FALSE FALSE
##  [517] FALSE FALSE FALSE FALSE FALSE FALSE FALSE FALSE FALSE FALSE FALSE FALSE
##  [529] FALSE FALSE FALSE FALSE FALSE FALSE FALSE FALSE FALSE FALSE FALSE FALSE
##  [541] FALSE FALSE FALSE FALSE FALSE FALSE FALSE FALSE FALSE FALSE FALSE FALSE
##  [553] FALSE FALSE FALSE FALSE FALSE FALSE FALSE FALSE FALSE FALSE FALSE FALSE
##  [565] FALSE FALSE FALSE FALSE FALSE FALSE FALSE FALSE FALSE FALSE FALSE FALSE
##  [577] FALSE FALSE FALSE FALSE FALSE FALSE FALSE FALSE FALSE FALSE FALSE FALSE
##  [589] FALSE FALSE FALSE FALSE FALSE FALSE FALSE FALSE FALSE FALSE FALSE FALSE
##  [601] FALSE FALSE FALSE FALSE FALSE FALSE FALSE FALSE FALSE FALSE FALSE FALSE
##  [613] FALSE FALSE FALSE FALSE FALSE FALSE FALSE FALSE FALSE FALSE FALSE FALSE
##  [625] FALSE FALSE FALSE FALSE FALSE FALSE FALSE FALSE FALSE FALSE FALSE FALSE
##  [637] FALSE FALSE FALSE FALSE FALSE FALSE FALSE FALSE FALSE FALSE FALSE FALSE
##  [649] FALSE FALSE FALSE FALSE FALSE FALSE FALSE FALSE FALSE FALSE FALSE FALSE
##  [661] FALSE FALSE FALSE FALSE FALSE FALSE FALSE FALSE FALSE FALSE FALSE FALSE
##  [673] FALSE FALSE FALSE FALSE FALSE FALSE FALSE FALSE FALSE FALSE FALSE FALSE
##  [685] FALSE FALSE FALSE FALSE FALSE FALSE FALSE FALSE FALSE FALSE FALSE FALSE
##  [697] FALSE FALSE FALSE FALSE FALSE FALSE FALSE FALSE FALSE FALSE FALSE FALSE
##  [709] FALSE FALSE FALSE FALSE FALSE FALSE FALSE FALSE FALSE FALSE FALSE FALSE
##  [721] FALSE FALSE FALSE FALSE FALSE FALSE FALSE FALSE FALSE FALSE FALSE FALSE
##  [733] FALSE FALSE FALSE FALSE FALSE FALSE FALSE FALSE FALSE FALSE FALSE FALSE
##  [745] FALSE FALSE FALSE FALSE FALSE FALSE FALSE FALSE FALSE FALSE FALSE FALSE
##  [757] FALSE FALSE FALSE FALSE FALSE FALSE FALSE FALSE FALSE FALSE FALSE FALSE
##  [769] FALSE FALSE FALSE FALSE FALSE FALSE FALSE FALSE FALSE FALSE FALSE FALSE
##  [781] FALSE FALSE FALSE FALSE FALSE FALSE FALSE FALSE FALSE FALSE FALSE FALSE
##  [793] FALSE FALSE FALSE FALSE FALSE FALSE FALSE FALSE FALSE FALSE FALSE FALSE
##  [805] FALSE FALSE FALSE FALSE FALSE FALSE FALSE FALSE FALSE FALSE FALSE FALSE
##  [817] FALSE FALSE FALSE FALSE FALSE FALSE FALSE FALSE FALSE FALSE FALSE FALSE
##  [829] FALSE FALSE FALSE FALSE FALSE FALSE FALSE FALSE FALSE FALSE FALSE FALSE
##  [841] FALSE FALSE FALSE FALSE FALSE FALSE FALSE FALSE FALSE FALSE FALSE FALSE
##  [853] FALSE FALSE FALSE FALSE FALSE FALSE FALSE FALSE FALSE FALSE FALSE FALSE
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##  [877] FALSE FALSE FALSE FALSE FALSE FALSE FALSE FALSE FALSE FALSE FALSE FALSE
##  [889] FALSE FALSE FALSE FALSE FALSE FALSE FALSE FALSE FALSE FALSE FALSE FALSE
##  [901] FALSE FALSE FALSE FALSE FALSE FALSE FALSE FALSE FALSE FALSE FALSE FALSE
##  [913] FALSE FALSE FALSE FALSE FALSE FALSE FALSE FALSE FALSE FALSE FALSE FALSE
##  [925] FALSE FALSE FALSE FALSE FALSE FALSE FALSE FALSE FALSE FALSE FALSE FALSE
##  [937] FALSE FALSE FALSE FALSE FALSE FALSE FALSE FALSE FALSE FALSE FALSE FALSE
##  [949] FALSE FALSE FALSE FALSE FALSE FALSE FALSE FALSE FALSE FALSE FALSE FALSE
##  [961] FALSE FALSE FALSE FALSE FALSE FALSE FALSE FALSE FALSE FALSE FALSE FALSE
##  [973] FALSE FALSE FALSE FALSE FALSE FALSE FALSE FALSE FALSE FALSE FALSE FALSE
##  [985] FALSE FALSE FALSE FALSE FALSE FALSE FALSE FALSE FALSE FALSE FALSE FALSE
##  [997] FALSE FALSE FALSE FALSE FALSE FALSE FALSE FALSE FALSE FALSE FALSE FALSE
## [1009] FALSE FALSE FALSE FALSE FALSE FALSE FALSE FALSE FALSE FALSE FALSE FALSE
## [1021] FALSE FALSE FALSE FALSE FALSE FALSE FALSE FALSE FALSE FALSE FALSE FALSE
## [1033] FALSE FALSE FALSE FALSE FALSE FALSE FALSE FALSE FALSE FALSE FALSE FALSE
## [1045] FALSE FALSE FALSE FALSE FALSE FALSE FALSE FALSE FALSE FALSE FALSE FALSE
## [1057] FALSE FALSE FALSE FALSE FALSE FALSE FALSE FALSE FALSE FALSE FALSE FALSE
## [1069] FALSE FALSE FALSE FALSE FALSE FALSE FALSE FALSE FALSE FALSE FALSE FALSE
## [1081] FALSE FALSE FALSE FALSE FALSE FALSE FALSE FALSE FALSE FALSE FALSE FALSE
## [1093] FALSE FALSE FALSE FALSE FALSE FALSE FALSE FALSE FALSE FALSE FALSE FALSE
## [1105] FALSE FALSE FALSE FALSE FALSE FALSE FALSE FALSE FALSE FALSE FALSE FALSE
## [1117] FALSE FALSE FALSE FALSE FALSE FALSE FALSE FALSE FALSE FALSE FALSE FALSE
## [1129] FALSE FALSE FALSE FALSE FALSE FALSE FALSE FALSE FALSE FALSE FALSE FALSE
## [1141] FALSE FALSE FALSE FALSE FALSE FALSE FALSE FALSE FALSE FALSE FALSE FALSE
## [1153] FALSE FALSE FALSE FALSE FALSE FALSE FALSE FALSE FALSE FALSE FALSE FALSE
## [1165] FALSE FALSE FALSE FALSE FALSE FALSE FALSE FALSE FALSE FALSE FALSE FALSE
## [1177] FALSE FALSE FALSE FALSE FALSE FALSE FALSE FALSE FALSE FALSE FALSE FALSE
## [1189] FALSE FALSE FALSE FALSE FALSE FALSE FALSE FALSE FALSE FALSE FALSE FALSE
## [1201] FALSE FALSE FALSE FALSE FALSE FALSE FALSE FALSE FALSE FALSE FALSE FALSE
## [1213] FALSE FALSE FALSE FALSE FALSE FALSE FALSE FALSE FALSE FALSE FALSE FALSE
## [1225] FALSE FALSE FALSE FALSE FALSE FALSE FALSE FALSE FALSE FALSE FALSE FALSE
## [1237] FALSE FALSE FALSE FALSE FALSE FALSE FALSE FALSE FALSE FALSE FALSE FALSE
## [1249] FALSE FALSE FALSE FALSE FALSE FALSE FALSE FALSE FALSE FALSE FALSE FALSE
## [1261] FALSE FALSE FALSE FALSE FALSE FALSE FALSE FALSE FALSE FALSE FALSE FALSE
## [1273] FALSE FALSE FALSE FALSE FALSE FALSE FALSE FALSE FALSE FALSE FALSE FALSE
## [1285] FALSE FALSE FALSE FALSE FALSE FALSE FALSE FALSE FALSE FALSE FALSE FALSE
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## [1309] FALSE FALSE FALSE FALSE FALSE FALSE FALSE FALSE FALSE FALSE FALSE FALSE
## [1321] FALSE FALSE FALSE FALSE FALSE FALSE FALSE FALSE FALSE FALSE FALSE FALSE
## [1333] FALSE FALSE FALSE FALSE FALSE FALSE FALSE FALSE FALSE FALSE FALSE FALSE
## [1345] FALSE FALSE FALSE FALSE FALSE FALSE FALSE FALSE FALSE FALSE FALSE FALSE
## [1357] FALSE FALSE FALSE FALSE FALSE FALSE FALSE FALSE FALSE FALSE FALSE FALSE
## [1369] FALSE FALSE FALSE FALSE FALSE FALSE FALSE FALSE FALSE FALSE FALSE FALSE
## [1381] FALSE FALSE FALSE FALSE FALSE FALSE FALSE FALSE FALSE FALSE FALSE FALSE
## [1393] FALSE FALSE FALSE FALSE FALSE FALSE FALSE FALSE FALSE FALSE FALSE FALSE
## [1405] FALSE FALSE FALSE FALSE FALSE FALSE FALSE FALSE FALSE FALSE FALSE FALSE
## [1417] FALSE FALSE FALSE FALSE FALSE FALSE FALSE FALSE FALSE FALSE FALSE FALSE
## [1429] FALSE FALSE FALSE FALSE FALSE FALSE FALSE FALSE FALSE FALSE FALSE FALSE
## [1441] FALSE FALSE FALSE FALSE FALSE FALSE FALSE FALSE FALSE FALSE FALSE FALSE
## [1453] FALSE FALSE FALSE FALSE FALSE FALSE FALSE FALSE FALSE FALSE FALSE FALSE
## [1465] FALSE FALSE FALSE FALSE FALSE FALSE FALSE FALSE FALSE FALSE FALSE FALSE
## [1477] FALSE FALSE FALSE FALSE FALSE FALSE FALSE FALSE FALSE FALSE FALSE FALSE
## [1489] FALSE FALSE FALSE FALSE FALSE FALSE FALSE FALSE FALSE FALSE FALSE FALSE
```

```r
fnames <- paste0("cat.", 1501:2000, ".jpg")
file.copy(file.path(original_dataset_dir, fnames),
          file.path(validation_cats_dir))
```

```
##   [1] FALSE FALSE FALSE FALSE FALSE FALSE FALSE FALSE FALSE FALSE FALSE FALSE
##  [13] FALSE FALSE FALSE FALSE FALSE FALSE FALSE FALSE FALSE FALSE FALSE FALSE
##  [25] FALSE FALSE FALSE FALSE FALSE FALSE FALSE FALSE FALSE FALSE FALSE FALSE
##  [37] FALSE FALSE FALSE FALSE FALSE FALSE FALSE FALSE FALSE FALSE FALSE FALSE
##  [49] FALSE FALSE FALSE FALSE FALSE FALSE FALSE FALSE FALSE FALSE FALSE FALSE
##  [61] FALSE FALSE FALSE FALSE FALSE FALSE FALSE FALSE FALSE FALSE FALSE FALSE
##  [73] FALSE FALSE FALSE FALSE FALSE FALSE FALSE FALSE FALSE FALSE FALSE FALSE
##  [85] FALSE FALSE FALSE FALSE FALSE FALSE FALSE FALSE FALSE FALSE FALSE FALSE
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## [121] FALSE FALSE FALSE FALSE FALSE FALSE FALSE FALSE FALSE FALSE FALSE FALSE
## [133] FALSE FALSE FALSE FALSE FALSE FALSE FALSE FALSE FALSE FALSE FALSE FALSE
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## [205] FALSE FALSE FALSE FALSE FALSE FALSE FALSE FALSE FALSE FALSE FALSE FALSE
## [217] FALSE FALSE FALSE FALSE FALSE FALSE FALSE FALSE FALSE FALSE FALSE FALSE
## [229] FALSE FALSE FALSE FALSE FALSE FALSE FALSE FALSE FALSE FALSE FALSE FALSE
## [241] FALSE FALSE FALSE FALSE FALSE FALSE FALSE FALSE FALSE FALSE FALSE FALSE
## [253] FALSE FALSE FALSE FALSE FALSE FALSE FALSE FALSE FALSE FALSE FALSE FALSE
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## [349] FALSE FALSE FALSE FALSE FALSE FALSE FALSE FALSE FALSE FALSE FALSE FALSE
## [361] FALSE FALSE FALSE FALSE FALSE FALSE FALSE FALSE FALSE FALSE FALSE FALSE
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## [469] FALSE FALSE FALSE FALSE FALSE FALSE FALSE FALSE FALSE FALSE FALSE FALSE
## [481] FALSE FALSE FALSE FALSE FALSE FALSE FALSE FALSE FALSE FALSE FALSE FALSE
## [493] FALSE FALSE FALSE FALSE FALSE FALSE FALSE FALSE
```

```r
fnames <- paste0("cat.", 2001:2500, ".jpg")
file.copy(file.path(original_dataset_dir, fnames),
          file.path(test_cats_dir))
```

```
##   [1] FALSE FALSE FALSE FALSE FALSE FALSE FALSE FALSE FALSE FALSE FALSE FALSE
##  [13] FALSE FALSE FALSE FALSE FALSE FALSE FALSE FALSE FALSE FALSE FALSE FALSE
##  [25] FALSE FALSE FALSE FALSE FALSE FALSE FALSE FALSE FALSE FALSE FALSE FALSE
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##  [49] FALSE FALSE FALSE FALSE FALSE FALSE FALSE FALSE FALSE FALSE FALSE FALSE
##  [61] FALSE FALSE FALSE FALSE FALSE FALSE FALSE FALSE FALSE FALSE FALSE FALSE
##  [73] FALSE FALSE FALSE FALSE FALSE FALSE FALSE FALSE FALSE FALSE FALSE FALSE
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## [445] FALSE FALSE FALSE FALSE FALSE FALSE FALSE FALSE FALSE FALSE FALSE FALSE
## [457] FALSE FALSE FALSE FALSE FALSE FALSE FALSE FALSE FALSE FALSE FALSE FALSE
## [469] FALSE FALSE FALSE FALSE FALSE FALSE FALSE FALSE FALSE FALSE FALSE FALSE
## [481] FALSE FALSE FALSE FALSE FALSE FALSE FALSE FALSE FALSE FALSE FALSE FALSE
## [493] FALSE FALSE FALSE FALSE FALSE FALSE FALSE FALSE
```

```r
fnames <- paste0("dog.", 1:1500, ".jpg")
file.copy(file.path(original_dataset_dir, fnames),
          file.path(train_dogs_dir))
```

```
##    [1] FALSE FALSE FALSE FALSE FALSE FALSE FALSE FALSE FALSE FALSE FALSE FALSE
##   [13] FALSE FALSE FALSE FALSE FALSE FALSE FALSE FALSE FALSE FALSE FALSE FALSE
##   [25] FALSE FALSE FALSE FALSE FALSE FALSE FALSE FALSE FALSE FALSE FALSE FALSE
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```

```r
fnames <- paste0("dog.", 1501:2000, ".jpg")
file.copy(file.path(original_dataset_dir, fnames),
          file.path(validation_dogs_dir))
```

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```

```r
fnames <- paste0("dog.", 2001:2500, ".jpg")
file.copy(file.path(original_dataset_dir, fnames),
          file.path(test_dogs_dir))
```

```
##   [1] FALSE FALSE FALSE FALSE FALSE FALSE FALSE FALSE FALSE FALSE FALSE FALSE
##  [13] FALSE FALSE FALSE FALSE FALSE FALSE FALSE FALSE FALSE FALSE FALSE FALSE
##  [25] FALSE FALSE FALSE FALSE FALSE FALSE FALSE FALSE FALSE FALSE FALSE FALSE
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## [469] FALSE FALSE FALSE FALSE FALSE FALSE FALSE FALSE FALSE FALSE FALSE FALSE
## [481] FALSE FALSE FALSE FALSE FALSE FALSE FALSE FALSE FALSE FALSE FALSE FALSE
## [493] FALSE FALSE FALSE FALSE FALSE FALSE FALSE FALSE
```
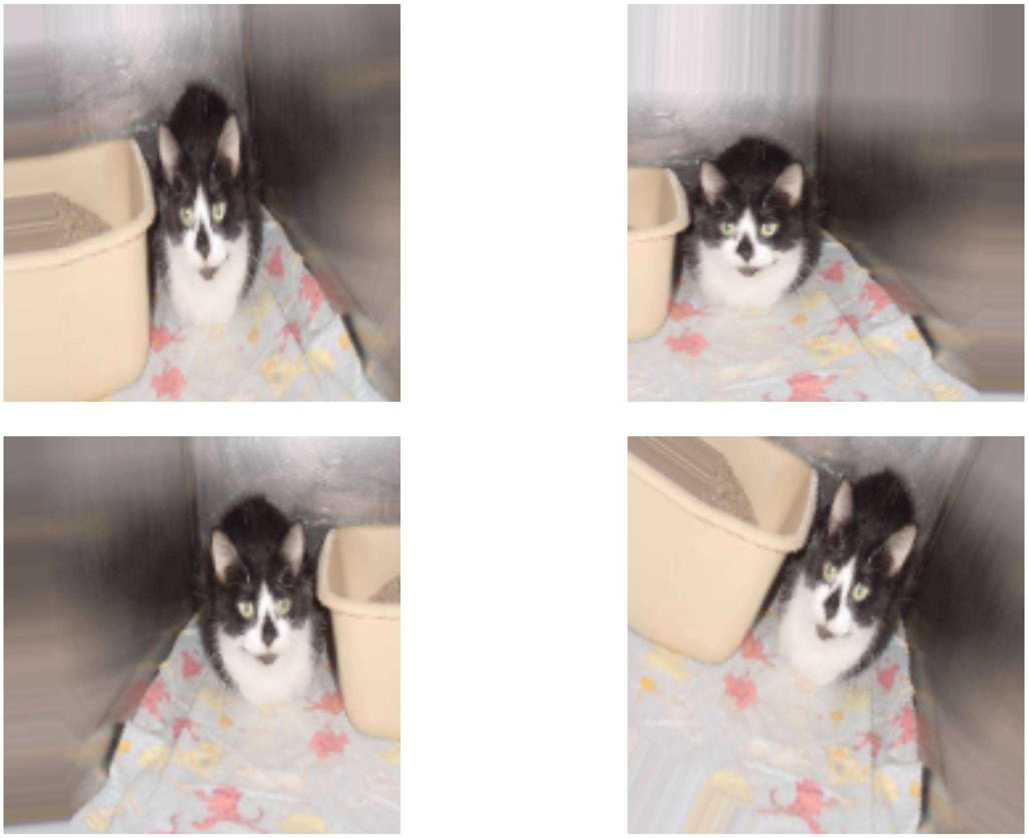
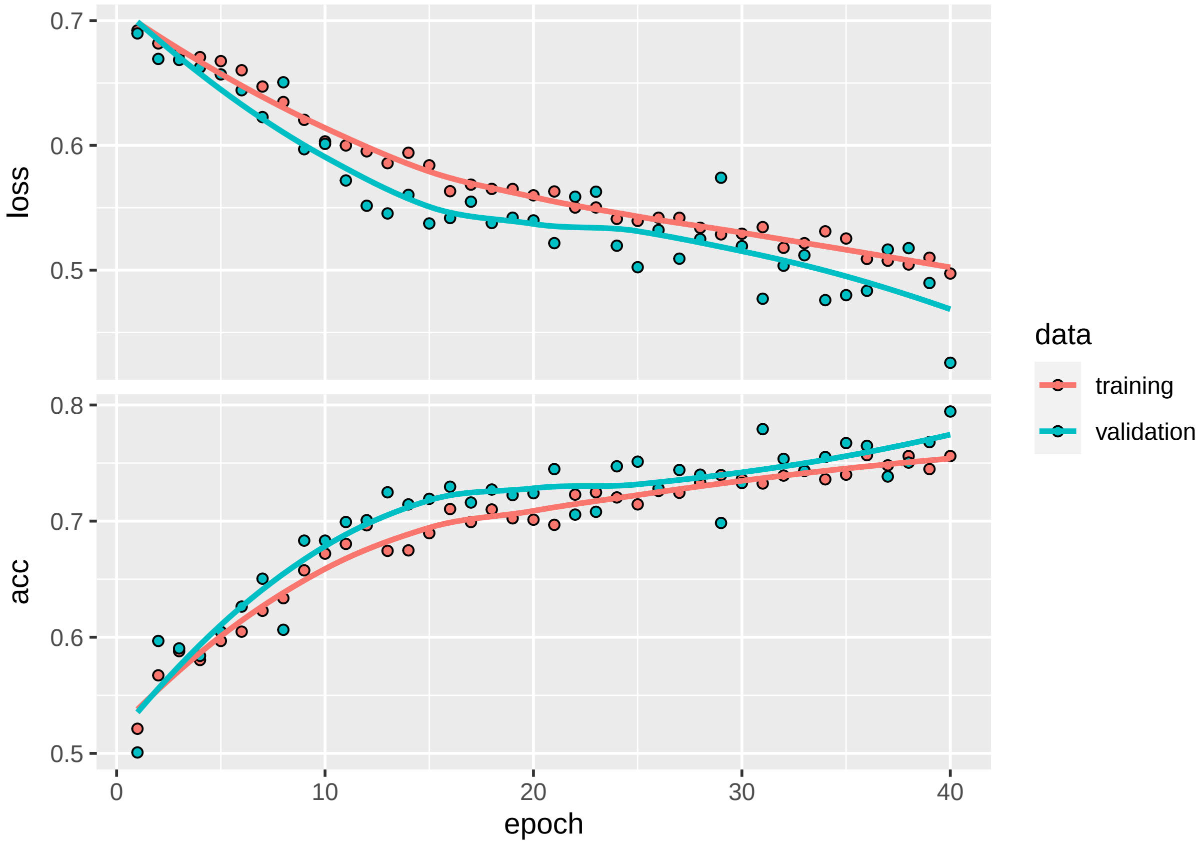

```r
datagen <- image_data_generator(
  rescale = 1/255,
  rotation_range = 40,
  width_shift_range = 0.2,
  height_shift_range = 0.2,
  shear_range = 0.2,
  zoom_range = 0.2,
  horizontal_flip = TRUE
)
fnames <- list.files(file.path(train_dir,"cats"), full.names = T)
img_path <- fnames[[round(runif(1,1,length(fnames)))]]
img <- image_load(img_path, target_size = c(150,150))
img_array <- image_to_array(img)
img_array <- array_reshape(img_array, c(1,150,150,3))
augmentation_generator <- flow_images_from_data(
    img_array,
    generator = datagen,
    batch_size = 1
)
op <- par(mfrow=c(2,2), pty="s", mar=c(1,0,.1,0))
for (i in 1:4) {
  batch <- generator_next(augmentation_generator)
  plot(as.raster(batch[1,,,]))
}
```



```
par(op)
model3 <- keras_model_sequential() %>%
  layer_conv_2d(filters = 32, kernel_size = c(3,3), activation = "relu", input_shape = c(150,150,3)) %>
  layer_max_pooling_2d(pool_size = c(2,2)) %>%
  layer_conv_2d(filters = 64, kernel_size = c(3,3), activation = "relu") %>%
  layer_max_pooling_2d(pool_size = c(2,2)) %>%
  layer_conv_2d(filters = 128, kernel_size = c(3,3), activation = "relu") %>%
  layer_max_pooling_2d(pool_size = c(2,2)) %>%
  layer_conv_2d(filters = 128, kernel_size = c(3,3), activation = "relu") %>%
  layer_max_pooling_2d(pool_size = c(2,2)) %>%
  layer_flatten() %>%
  layer_dropout(rate = 0.5) %>%
  layer_dense(units=512, activation = "relu") %>%
  layer_dense(units=1, activation = "sigmoid")
model3 %>% compile(
  loss = "binary_crossentropy",
  optimizer = optimizer_rmsprop(learning_rate = 1e-4),
  metrics = c("acc")
)
test_datagen <- image_data_generator(rescale = 1/255)
train_generator <- flow_images_from_directory(
  train_dir,
  datagen,
  target_size = c(150, 150),
  batch_size = 25,
  class_mode = "binary"
)
validation_generator <- flow_images_from_directory(
  validation_dir,
  test_datagen,
  target_size = c(150, 150),
  batch_size = 25,
  class_mode = "binary"
)
history3 <- model3 %>% fit(
  train_generator,
  steps_per_epoch = 100,
  epochs = 40,
  validation_data = validation_generator,
  validation_steps = 50
)
test_generator <- flow_images_from_directory(
  test_dir,
  test_datagen,
  target_size = c(150, 150),
  batch_size = 20,
  class_mode = "binary"
)
plot(history3)
```



```
model3 %>% evaluate_generator(test_generator, steps = 50)
```

```
##      loss       acc
## 0.4895864 0.7570000
```

This model has a loss of .485 and an accuracy of .76 . Small improvement over the model with less training images. Slightly lower loss and accuracy than the previous model.

Question 3

The following model has the same number of training images, but increases by 500 of validation and testing images.

```
dir.create(base_dir)
train_dir <- file.path(base_dir, "train")
dir.create(train_dir)
validation_dir <- file.path(base_dir, "validation")
dir.create(validation_dir)
test_dir <- file.path(base_dir, "test")
dir.create(test_dir)
train_cats_dir <- file.path(train_dir, "cats")
dir.create(train_cats_dir)
train_dogs_dir <- file.path(train_dir, "dogs")
dir.create(train_dogs_dir)
validation_cats_dir <- file.path(validation_dir, "cats")
dir.create(validation_cats_dir)
validation_dogs_dir <- file.path(validation_dir, "dogs")
dir.create(validation_dogs_dir)
test_cats_dir <- file.path(test_dir, "cats")
dir.create(test_cats_dir)
test_dogs_dir <- file.path(test_dir, "dogs")
dir.create(test_dogs_dir)
fnames <- paste0("cat.", 1:1500, ".jpg")
file.copy(file.path(original_dataset_dir, fnames),
          file.path(train_cats_dir))
```

```
##    [1] FALSE FALSE FALSE FALSE FALSE FALSE FALSE FALSE FALSE FALSE FALSE FALSE
##   [13] FALSE FALSE FALSE FALSE FALSE FALSE FALSE FALSE FALSE FALSE FALSE FALSE
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## [1489] FALSE FALSE FALSE FALSE FALSE FALSE FALSE FALSE FALSE FALSE FALSE FALSE
```

```
fnames <- paste0("cat.", 1501:2250, ".jpg")
file.copy(file.path(original_dataset_dir, fnames),
          file.path(validation_cats_dir))
```

```
##   [1] FALSE FALSE FALSE FALSE FALSE FALSE FALSE FALSE FALSE FALSE FALSE FALSE
##  [13] FALSE FALSE FALSE FALSE FALSE FALSE FALSE FALSE FALSE FALSE FALSE FALSE
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## [721] FALSE FALSE FALSE FALSE FALSE FALSE FALSE FALSE FALSE FALSE FALSE FALSE
## [733] FALSE FALSE FALSE FALSE FALSE FALSE FALSE FALSE FALSE FALSE FALSE FALSE
## [745] FALSE FALSE FALSE FALSE FALSE FALSE
```

```
fnames <- paste0("cat.", 2251:3000, ".jpg")
file.copy(file.path(original_dataset_dir, fnames),
          file.path(test_cats_dir))
```

```
##   [1] FALSE FALSE FALSE FALSE FALSE FALSE FALSE FALSE FALSE FALSE FALSE FALSE
##  [13] FALSE FALSE FALSE FALSE FALSE FALSE FALSE FALSE FALSE FALSE FALSE FALSE
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## [721] FALSE FALSE FALSE FALSE FALSE FALSE FALSE FALSE FALSE FALSE FALSE FALSE
## [733] FALSE FALSE FALSE FALSE FALSE FALSE FALSE FALSE FALSE FALSE FALSE FALSE
## [745] FALSE FALSE FALSE FALSE FALSE FALSE
```

```r
fnames <- paste0("dog.", 1:1500, ".jpg")
file.copy(file.path(original_dataset_dir, fnames),
          file.path(train_dogs_dir))
```

```
##    [1] FALSE FALSE FALSE FALSE FALSE FALSE FALSE FALSE FALSE FALSE FALSE FALSE
##   [13] FALSE FALSE FALSE FALSE FALSE FALSE FALSE FALSE FALSE FALSE FALSE FALSE
##   [25] FALSE FALSE FALSE FALSE FALSE FALSE FALSE FALSE FALSE FALSE FALSE FALSE
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##  [433] FALSE FALSE FALSE FALSE FALSE FALSE FALSE FALSE FALSE FALSE FALSE FALSE
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##  [745] FALSE FALSE FALSE FALSE FALSE FALSE FALSE FALSE FALSE FALSE FALSE FALSE
##  [757] FALSE FALSE FALSE FALSE FALSE FALSE FALSE FALSE FALSE FALSE FALSE FALSE
##  [769] FALSE FALSE FALSE FALSE FALSE FALSE FALSE FALSE FALSE FALSE FALSE FALSE
##  [781] FALSE FALSE FALSE FALSE FALSE FALSE FALSE FALSE FALSE FALSE FALSE FALSE
##  [793] FALSE FALSE FALSE FALSE FALSE FALSE FALSE FALSE FALSE FALSE FALSE FALSE
##  [805] FALSE FALSE FALSE FALSE FALSE FALSE FALSE FALSE FALSE FALSE FALSE FALSE
##  [817] FALSE FALSE FALSE FALSE FALSE FALSE FALSE FALSE FALSE FALSE FALSE FALSE
##  [829] FALSE FALSE FALSE FALSE FALSE FALSE FALSE FALSE FALSE FALSE FALSE FALSE
##  [841] FALSE FALSE FALSE FALSE FALSE FALSE FALSE FALSE FALSE FALSE FALSE FALSE
##  [853] FALSE FALSE FALSE FALSE FALSE FALSE FALSE FALSE FALSE FALSE FALSE FALSE
##  [865] FALSE FALSE FALSE FALSE FALSE FALSE FALSE FALSE FALSE FALSE FALSE FALSE
##  [877] FALSE FALSE FALSE FALSE FALSE FALSE FALSE FALSE FALSE FALSE FALSE FALSE
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## [1465] FALSE FALSE FALSE FALSE FALSE FALSE FALSE FALSE FALSE FALSE FALSE FALSE
## [1477] FALSE FALSE FALSE FALSE FALSE FALSE FALSE FALSE FALSE FALSE FALSE FALSE
## [1489] FALSE FALSE FALSE FALSE FALSE FALSE FALSE FALSE FALSE FALSE FALSE FALSE
```

```r
fnames <- paste0("dog.", 1501:2250, ".jpg")
file.copy(file.path(original_dataset_dir, fnames),
          file.path(validation_dogs_dir))
```

```
##   [1] FALSE FALSE FALSE FALSE FALSE FALSE FALSE FALSE FALSE FALSE FALSE FALSE
##  [13] FALSE FALSE FALSE FALSE FALSE FALSE FALSE FALSE FALSE FALSE FALSE FALSE
##  [25] FALSE FALSE FALSE FALSE FALSE FALSE FALSE FALSE FALSE FALSE FALSE FALSE
##  [37] FALSE FALSE FALSE FALSE FALSE FALSE FALSE FALSE FALSE FALSE FALSE FALSE
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## [733] FALSE FALSE FALSE FALSE FALSE FALSE FALSE FALSE FALSE FALSE FALSE FALSE
## [745] FALSE FALSE FALSE FALSE FALSE FALSE
```

```r
fnames <- paste0("dog.", 2251:3000, ".jpg")
file.copy(file.path(original_dataset_dir, fnames),
          file.path(test_dogs_dir))
```

```
##   [1] FALSE FALSE FALSE FALSE FALSE FALSE FALSE FALSE FALSE FALSE FALSE FALSE
##  [13] FALSE FALSE FALSE FALSE FALSE FALSE FALSE FALSE FALSE FALSE FALSE FALSE
##  [25] FALSE FALSE FALSE FALSE FALSE FALSE FALSE FALSE FALSE FALSE FALSE FALSE
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## [697] FALSE FALSE FALSE FALSE FALSE FALSE FALSE FALSE FALSE FALSE FALSE FALSE
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## [721] FALSE FALSE FALSE FALSE FALSE FALSE FALSE FALSE FALSE FALSE FALSE FALSE
## [733] FALSE FALSE FALSE FALSE FALSE FALSE FALSE FALSE FALSE FALSE FALSE FALSE
## [745] FALSE FALSE FALSE FALSE FALSE FALSE
```
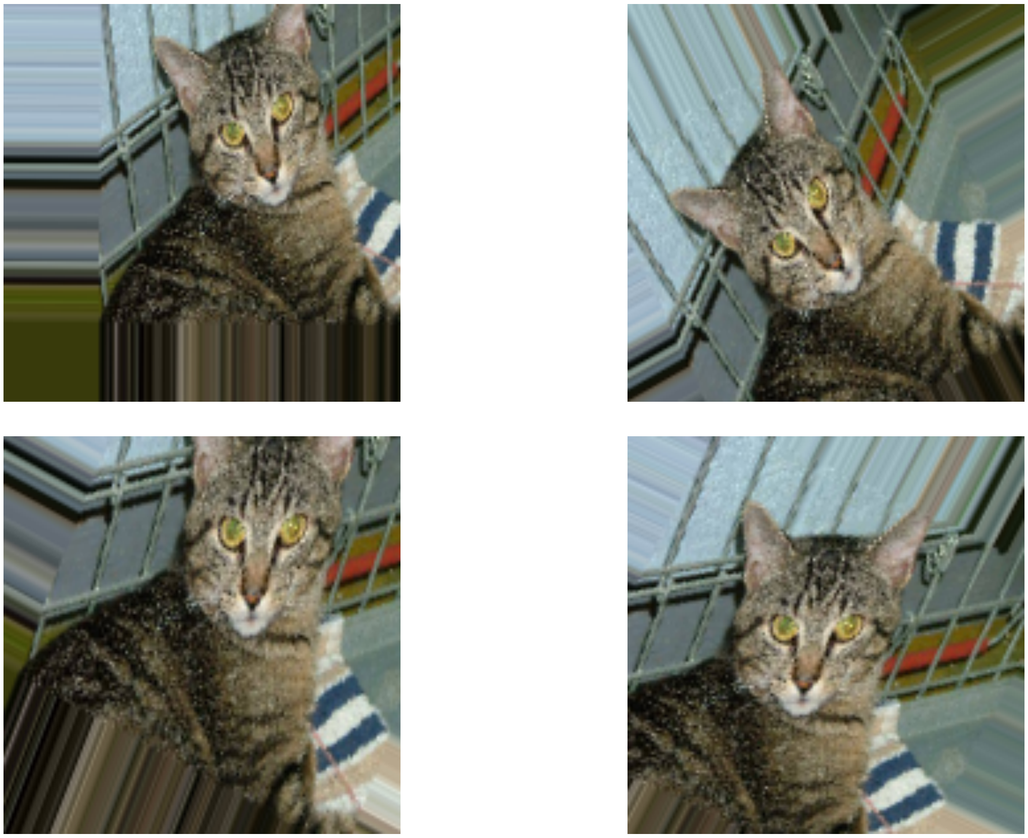
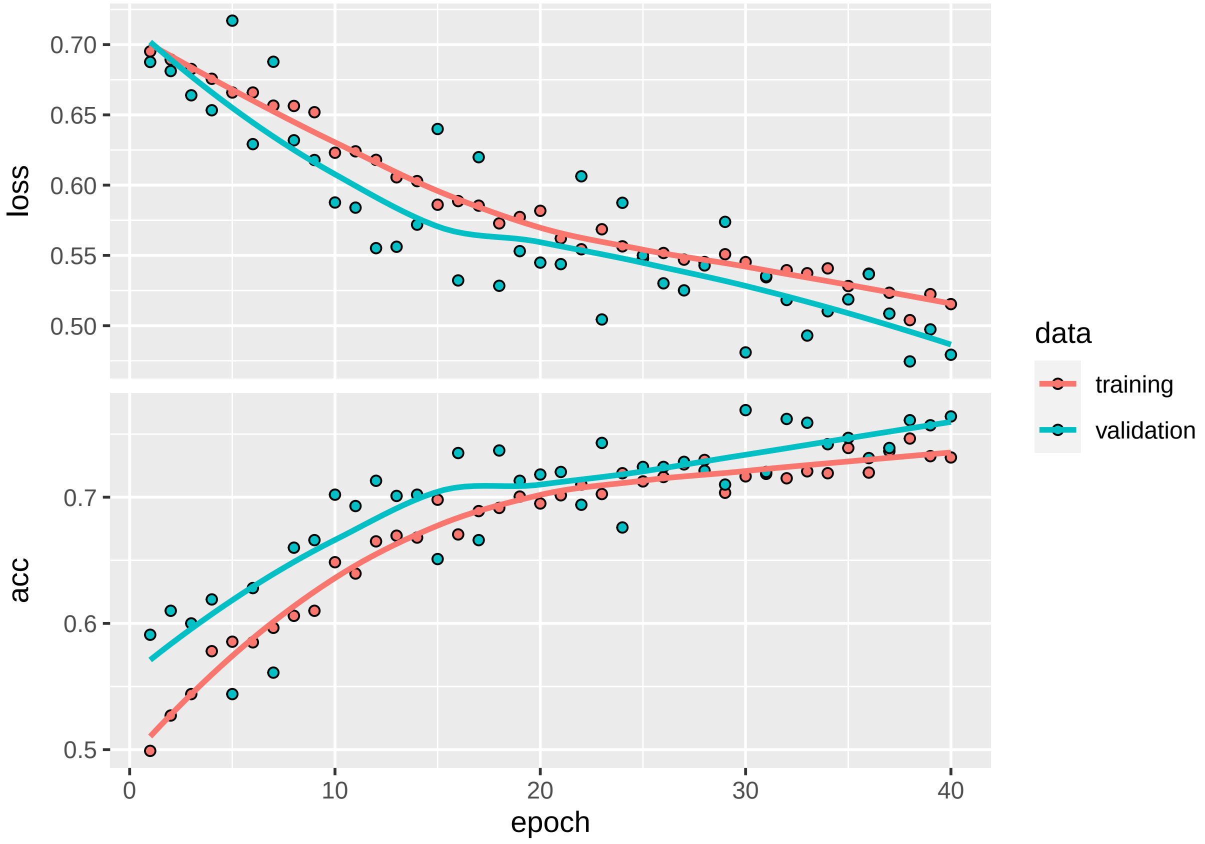

```r
datagen <- image_data_generator(
  rescale = 1/255,
  rotation_range = 40,
  width_shift_range = 0.2,
  height_shift_range = 0.2,
  shear_range = 0.2,
  zoom_range = 0.2,
  horizontal_flip = TRUE
)
fnames <- list.files(file.path(train_dir,"cats"), full.names = T)
img_path <- fnames[[round(runif(1,1,length(fnames)))]]
img <- image_load(img_path, target_size = c(150,150))
img_array <- image_to_array(img)
img_array <- array_reshape(img_array, c(1,150,150,3))
augmentation_generator <- flow_images_from_data(
    img_array,
    generator = datagen,
    batch_size = 1
)
op <- par(mfrow=c(2,2), pty="s", mar=c(1,0,.1,0))
for (i in 1:4) {
  batch <- generator_next(augmentation_generator)
  plot(as.raster(batch[1,,,]))
}
```



```
par(op)
model4 <- keras_model_sequential() %>%
  layer_conv_2d(filters = 32, kernel_size = c(3,3), activation = "relu", input_shape = c(150,150,3)) %>
  layer_max_pooling_2d(pool_size = c(2,2)) %>%
  layer_conv_2d(filters = 64, kernel_size = c(3,3), activation = "relu") %>%
  layer_max_pooling_2d(pool_size = c(2,2)) %>%
  layer_conv_2d(filters = 128, kernel_size = c(3,3), activation = "relu") %>%
  layer_max_pooling_2d(pool_size = c(2,2)) %>%
  layer_conv_2d(filters = 128, kernel_size = c(3,3), activation = "relu") %>%
  layer_max_pooling_2d(pool_size = c(2,2)) %>%
  layer_flatten() %>%
  layer_dropout(rate = 0.5) %>%
  layer_dense(units=512, activation = "relu") %>%
  layer_dense(units=1, activation = "sigmoid")
model4 %>% compile(
  loss = "binary_crossentropy",
  optimizer = optimizer_rmsprop(learning_rate = 1e-4),
  metrics = c("acc")
)
test_datagen <- image_data_generator(rescale = 1/255)
train_generator <- flow_images_from_directory(
  train_dir,
  datagen,
  target_size = c(150, 150),
  batch_size = 20,
  class_mode = "binary"
)
validation_generator <- flow_images_from_directory(
  validation_dir,
  test_datagen,
  target_size = c(150, 150),
  batch_size = 20,
  class_mode = "binary"
)
history4 <- model4 %>% fit(
  train_generator,
  steps_per_epoch = 100,
  epochs = 40,
  validation_data = validation_generator,
  validation_steps = 50
)
test_datagen <- image_data_generator(rescale = 1/255)
test_generator <- flow_images_from_directory(
  test_dir,
  test_datagen,
  target_size = c(150, 150),
  batch_size = 20,
  class_mode = "binary"
)
plot(history4)
```



```
model4 %>% evaluate_generator(test_generator, steps = 50)
```

```
##      loss       acc
## 0.5248497 0.7420000
```

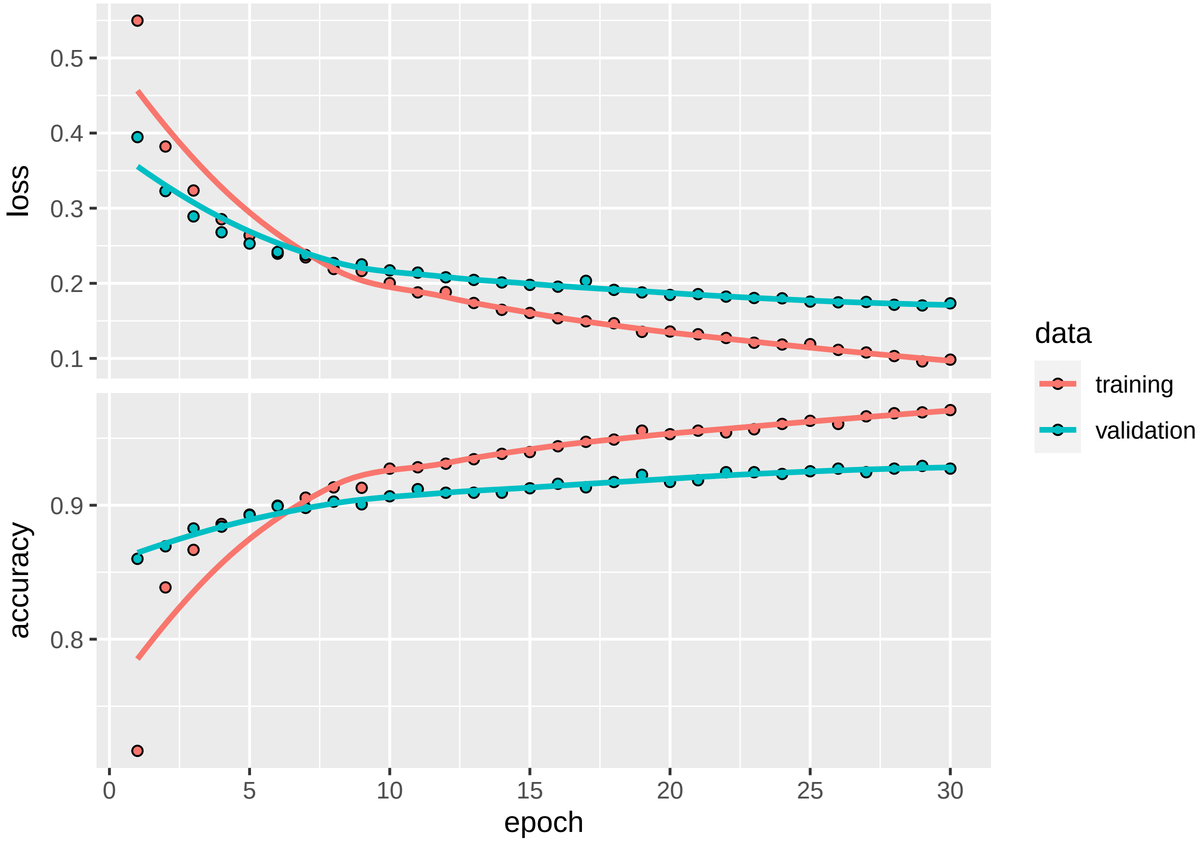
This model now has a loss of .515 and an accuarcy of .747. This has a higher loss and slightly lower accuracy than the previous model This is worse than the model with less training and validation data.

Question 4:

The final model uses feature extraction

```
conv_base <- application_vgg16(
  weights = "imagenet",
  include_top = FALSE,
  input_shape = c(150, 150, 3)
 )
 base_dir <- "~/Downloads/cats_and_dogs_small"
 train_dir <- train_dir <- file.path(base_dir, "train")
 validation_dir <- validation_dir <- file.path(base_dir, "validation")
 test_dir <- test_dir <- file.path(base_dir, "test")
 datagen <- image_data_generator(rescale = 1/255)
 batch_size <- 20
 extract_features <- function(directory, sample_count) {
  features <- array(0, dim = c(sample_count, 4, 4, 512))
  labels <- array(0, dim = c(sample_count))
  generator <- flow_images_from_directory(
   directory = directory,
   generator = datagen,
   target_size = c(150, 150),
   batch_size = batch_size,
   class_mode = "binary"
  )
  i <- 0
  while(TRUE) {
   batch <- generator_next(generator)
   inputs_batch <- batch[[1]]
   labels_batch <- batch[[2]]
   features_batch <- conv_base %>% predict(inputs_batch)
   index_range <- ((i * batch_size)+1):((i+1) * batch_size)
   features[index_range,,,] <- features_batch
   labels[index_range] <- labels_batch
   i <- i + 1
   if (i * batch_size >= sample_count)
    break
  }
  list(
   features = features,
   labels = labels
  )
 }
```

```r
train <- extract_features(train_dir, 3000)
validation <- extract_features(validation_dir, 1500)
test <- extract_features(test_dir, 1500)

reshape_features <- function(features) {
  array_reshape(features, dim = c(nrow(features), 4 * 4 * 512))
}
train$features <-reshape_features(train$features)
validation$features <- reshape_features(validation$features)
test$features <- reshape_features(test$features)

model5 <- keras_model_sequential() %>%
  layer_dense(units = 256, activation = "relu", input_shape = 4 * 4 * 512) %>%
  layer_dropout(rate = 0.5) %>%
  layer_dense(units = 1, activation = "sigmoid")
model5 %>% compile(
  optimizer = optimizer_rmsprop(learning_rate = 2e-5),
  loss = "binary_crossentropy",
  metrics = c("accuracy")
)
History5 <- model5 %>% fit(
  train$features, train$labels,
  epochs = 30,
  batch_size = 20,
  validation_data = list(validation$features, validation$labels)
)

plot(History5)
```



```
model5 %>% evaluate(test$features, test$labels)
```

```
##      loss  accuracy
## 0.2569493 0.8960000
```

This model has a loss of .244 and and an accuracy of .898. This has a lower loss and higher accuracy than model 4. This shows a higher level of overfitting than the previous models, but less overfitting than the first model.