University of Technology, Sydney

Faculty of Engineering and Information Technology

EVALUATE DEEP NEURAL NETWORKS FOR CLASSIFICATION OF PNEUMONIA IN CHEST XRAY

by

Dung Quoc Thai

Student Number: 11990405

Project Number S18-209

Major: ICT Engineering

Supervisor: Professor John Canning

A 6 Credit Point Project submitted in partial fulfilment of the requirement

for the Degree of Bachelor of Engineering

22nd of June 2020

Statement of Originality

I, Dung Quoc Thai, hereby certify that this assignment is my own work, based on my personal study and/or research and that I have acknowledged all material and sources used in the preparation of this assignment.

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Name: Dung Quoc Thai

UTS Student Identification Number: 11990405

Date: 22nd of June 2020

Abstract

Artificial Intelligence (AI), specifically machine learning has been on the rise in recent years as the result of data availability. The approach to AI has moved toward more statistical learning-based methods where machines learn and modelled from big data without being explicitly programmed (Launchbury 2017). This advancement has brought forward the adoption of more efficient solutions to Computer-Vision problems to assist human in everyday life and more importantly, support experts in the medical field.

In 2016, diseases such as pneumonia accounted for over 16% of all deaths of children under five years old internationally (WHO 2016). In first world counties such as the United States, pneumonia accounts for over 500,000 visits to emergency departments (Rui & Kang 2015) and over 50,000 deaths in 2015 (Murphy *et al.* 2017). The cost of antibiotic treatment for children with pneumonia in 66 of the 2015 countdown countries estimates at around US$ 109 million per year (WHO 2016). Diagnostic of pneumonia requires the review of chest radiographs (CXR)s by highly trained specialists, confirmation through clinical history, vital signs and laboratory exams (RSNA 2018). However, diagnosing pneumonia using CXR is challenging even for experts due to potential influence from other conditions inside and outside the lungs, high volume of CXRs reading and other factors when obtaining CXRs (Kelly 2012).

This project explores the application of machine learning to assist experts in diagnosis and analysis of thorax diseases by prototyping a deep learning algorithm to detect visual signals of pneumonia infection. A collection of Convolutional Neural Networks (CNN)s which include VGG16 (Simonyan & Zisserman 2014), ResNet50V2 (He *et al.* 2016b), NasNetMobile (Zoph & Le 2016) and InceptionResNetV2 (Szegedy *et al.* 2017) were modified, trained and tested on the Mendeley chest x-ray dataset (Kermany *et al.* 2018) for the task. The F1-score achieved by the best model in this project (VGG16 model 1 version 1.1.1.0.0) shows that it outperformed similar works reviewed such as Rajpurkar *et al.* (2017); 0.942 vs 0.435 respectively. However, it was an unfeasible comparison since these projects are conducted on different datasets.

In the end, the project shows that the application of machine learning in computer-aided technology has promising potential to assist and improve medical experts' diagnoses and analysis. The advancement of AI is undoubtedly beneficial to humanity in the current stage.

Acknowledgements

I would like to extend my most profound appreciation and gratitude to my supervisor: Professor John Canning, of the School of Electrical & Data Engineering at the University of Technology Sydney. I am thankful for his feedback, guidance and most importantly patience throughout the period of my capstone as it has been quite a journey for me, not just academically but also personally.

I would also like to extend my thanks to Dr Mojtaba Golzan, of the Vision Science lab at UTS for his guidance during the initial period of my capstone project.

To my counsellor Nadine Neukirch, my family and friends for their continuous support throughout this period.

And to my late grandfather who was the inspiration to this project.

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Nomenclatures

CXR	Chest Radiograph/ Chest X-Ray
AI	Artificial Intelligent
ML	Machine Learning
NN	Neural Network
RNN/DNN	Regular Neural Network/ Deep Neural Network
CNN	Convolutional Neural Network
AG-CNN	Attention Guided Convolution Neural Network
NAS	Neural Architecture Search
FC	Fully Connected
ReLU	Rectified Linear Unit
ROC Curve	Receiver Operating Characteristic Curve
AUC	Area under the ROC Curve
WHO	World Health Organisation
RSNA	Radiological Society of North America

1 Introduction

1.1 Introducing the problem

Pneumonia accounts for over 16% of all deaths of children under five years old internationally. In 2015, 920,136 children under the age of 5 died from the disease (WHO 2016). In first world countries such as the United States, pneumonia accounts for over 500,000 visits to emergency departments (Rui & Kang 2015) and over 50,000 deaths in 2015 (Murphy *et al.* 2017), keeping the infection on the list of top 10 causes of death in the country. The cost of antibiotic treatment for children with pneumonia in 66 of the 2015 countdown countries including maternal, newborn and child survival estimates at around US$ 109 million per year (WHO 2016).

Diagnostic of pneumonia requires the review of chest radiographs (CXR)s by highly trained specialists, confirmation through clinical history, vital signs and laboratory exams (RSNA 2018). However, diagnosis pneumonia using CXR is challenging even for experts due to potential influence from other conditions inside and outside the lungs, high volume of CXRs reading and other factors when obtaining CXRs (Kelly 2012).

1.1.1 About pneumonia

Pneumonia is a lung infection caused by either bacteria, viruses, or fungi. The infection and the body's immune response cause the sacks in the lungs to fill with fluids instead of air hence produces opacity in CXRs of the lungs (see figure 1).

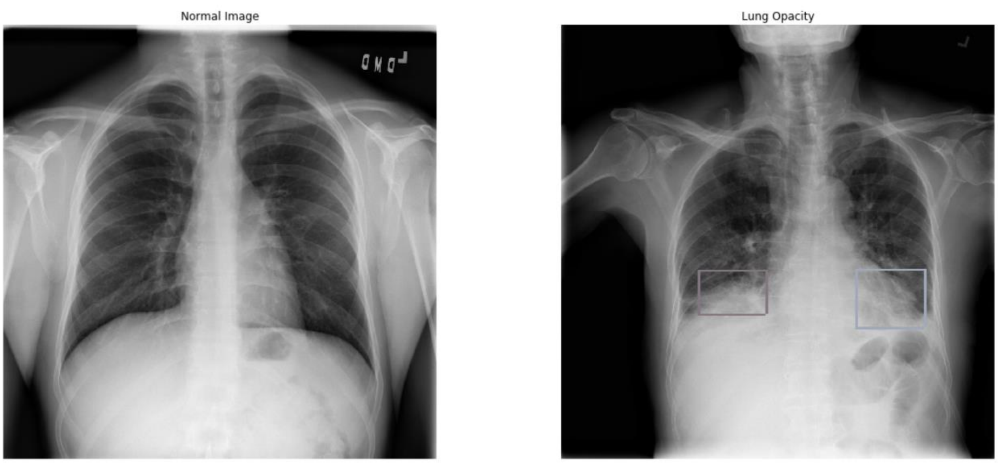

Figure 1: Normal vs. Lung Opacity (Zahavi 2018)

When comparing CXRs of pneumonia to other diseases, pneumonia associated lung opacities look diffuse on the CXR because the infection and fluid that accumulate spread within the normal tree of airways in the lung, thus, there is no clear border where the infection stops (see figure 1 – right image or figure 2 – left image). Other diseases like tumour that do not maintain the normal structure of the airways inside the lung (see figure 2 – right image).

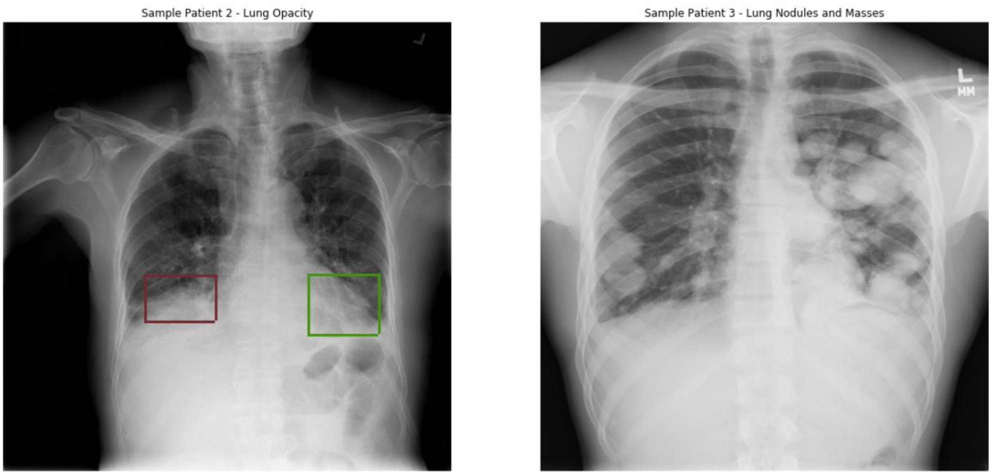

Figure 2:Pneumonia Lung Opacity vs. Potential Tumour (Zahavi 2018)

1.2 Introducing Artificial Intelligence

Artificial Intelligence (AI) is defined as "a cross-disciplinary approach to understanding, modelling and replicating intelligence and cognitive processes by invoking various computational, mathematical, logical, mechanical and even biological principles and devices." by Frankish & Ramsey (2014).

The application of AI is beneficial to digitize cognitive capabilities where it is challenging to program all the required rules and processes; an example of this is the image recognition process. An old "handcrafted" approach to creating an image recognition system would be to program all the relevant rules; this is sometimes referred to as the first wave of AI (Launchbury 2017). In recent time, the approach to AI has moved toward more statistical learning-based methods where machines learn and modelled from big data without being explicitly programmed; this is a concept known as machine learning and deep learning (Launchbury 2017).

1.3 *A Computer Vision Problem*

From an engineering point of view, computer vision may be regarded as the ability for a machine to perform tasks which a human visual system can perform or even surpass it (Huang 1996). In the recent decade, deep learning has unlocked the ability to build computer vision system capable of solving extraordinary tasks that would have been impossible in the past (Amini 2019). An example of deep learning in computer vision is facial recognition where data are coming into a deep neural network in the form of images or pixels or video and out of the network detecting human face, recognising key facial feature or even emotion (Amini 2019). Deep learning has transformed the computer vision field by removing the need for human operators to specify all the steps that the machine required to carry out the task on hand (Goodfellow *et al.* 2016). The creators can instead provide a large amount of data to the algorithm and even extract features from the existing network to carry different tasks (Amini 2019). These concepts are further explained and realised in this project as a convolutional neural network (CNN) and transfer learning.

1.3.1 Convolutional Neural Network

Convolutional Neural Network (CNN) is a network architecture for deep learning inspired by the connectivity pattern of Neurons in the Human Brain and the organization of the Visual Cortex (Saha 2018) which has been widely adopted for Computer-Vision problems because of its practicality and efficiency for recognising objects in images. A CNN could be used to progressively extract higher-level features of the image instead of preprocessing the data to derive features such as shapes and textures performed by early computer vision models (Google Developers 2018).

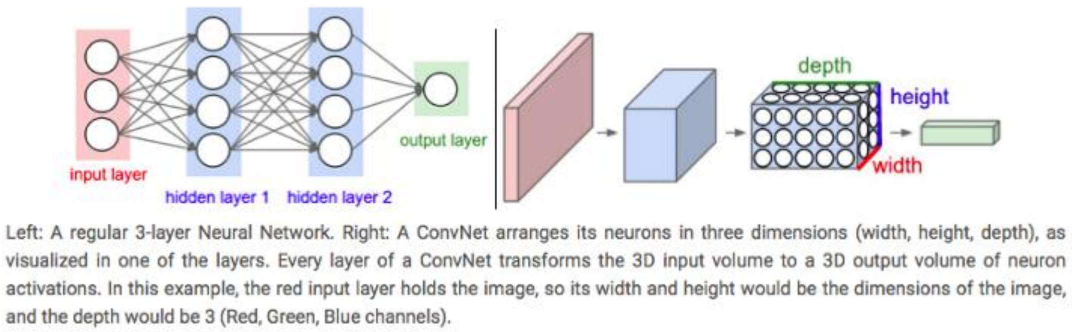

Figure 3: Example of a "Regular" Deep Neural Network and a Convolutional Neural Network (Li et al. 2018)

1.3.1.1 Briefly on Regular Neural Network

Regular Deep Neural Networks shortens to Regular Neural Networks (RNN)s receive an input (a single vector) and transform an input by putting it through a series of hidden layers (Li *et al.* 2018). Every layer is made up of a set of neurons, where each layer is fully connected to all neurons in the layer before, and neurons in a single layer function completely independently and do not share any connections (Patel and Pingel 2017). The last fully-connected layer (the output layer) present the prediction also known as the class scores in classification settings (see figure 3 – left).

The problem with RNNs for image classification is that RNNs do not scale well to full images (Li *et al.* 2018). For images of size 32x32x3 (32 wide, 32 high and 3 colour channels), a single fully-connected neuron in the first hidden layer of an RNN would have 3072 weights (32*32*3). This amount is manageable; however, for an image of more respectable size, e.g. 200x200x3, the neurons would have 120,000 weights. Moreover, an RNN usually consists of multiple FC layers, so that the parameters would add up quickly. Li *et al.* (2018) expressed that the full connectivity is wasteful and the considerable number of parameters would lead to overfitting showing that the fully-connected structure of the RNN does not scale to larger images.

1.3.1.2 More about CNN

CNN has many similarities to RNN since the network is made up of neurons that have learnable weights and biases. Similarly, each neuron in a CNN receives some inputs, performs a dot product and optionally follows it with a non-linearity (Li *et al.* 2018). The network also expresses a single differentiable score function with class scores at the final dense layer using loss function such as SVM or SoftMax (Li *et al.* 2018). Therefore, most training processes and techniques developed for RNNs are applicable to CNNs.

The distinct feature of CNNs, when compared to RNNs, is that CNN architecture explicitly assumes that the inputs are images, which allow certain properties to be encoded into the architecture of the network to improves the forward function efficiency and reduces the number of parameters in the network (Li *et al.* 2018). In simple term, CNN is a sequence of layers, where every layer transforms one volume of activations to another through a differentiable function. There are three main types of layers to build CNN architectures: Convolutional Layer, Pooling Layer, and Fully Connected Layer (Li *et al.* 2018). These layers are stacked to form a full CNN architecture. The section below explores each of these layers. Noted that the architecture of a CNN is always evolving, with the conventional paradigm of a linear stack of layers challenged by works such ResNet (He *et al.* 2016b) or InceptionResNet (Szegedy *et al.* 2017) that features more intricate and different connectivity structures (Li *et al.* 2018).

1.3.1.2.1 Convolution

An image input to a CNNs is the first *input feature map*: a three-dimensional matrix with the size of the first two dimensions corresponds to the length and width of the images in pixel and the third dimension, depth, corresponds to the channels of image colour (e.g. depth is 3 for red, green and blue (RGB) image) (Google Developers 2018).

A convolution extracts small region from input feature map and applies filters to them to compute new features, producing an output feature map, or convolved feature (which may have a different size and depth than the input feature map) (Google Developers 2018). These convolutions are defined by two parameters: the size of the extracted region and the depth of the output feature map. The extracted regions are known as local receptive fields (Patel & Pingel 2017) typically 3x3 or 5x5 pixels. The depth of an output feature map corresponds to the number of filters that are applied (Google Developers 2018).

During a forward pass, each convolutional filter (a matrix equal the size of the local receptive field) slide (more precisely, convolve) over the input feature map's grid horizontally and vertically, one pixel at a time, extracting each corresponding cell (see figure 4).

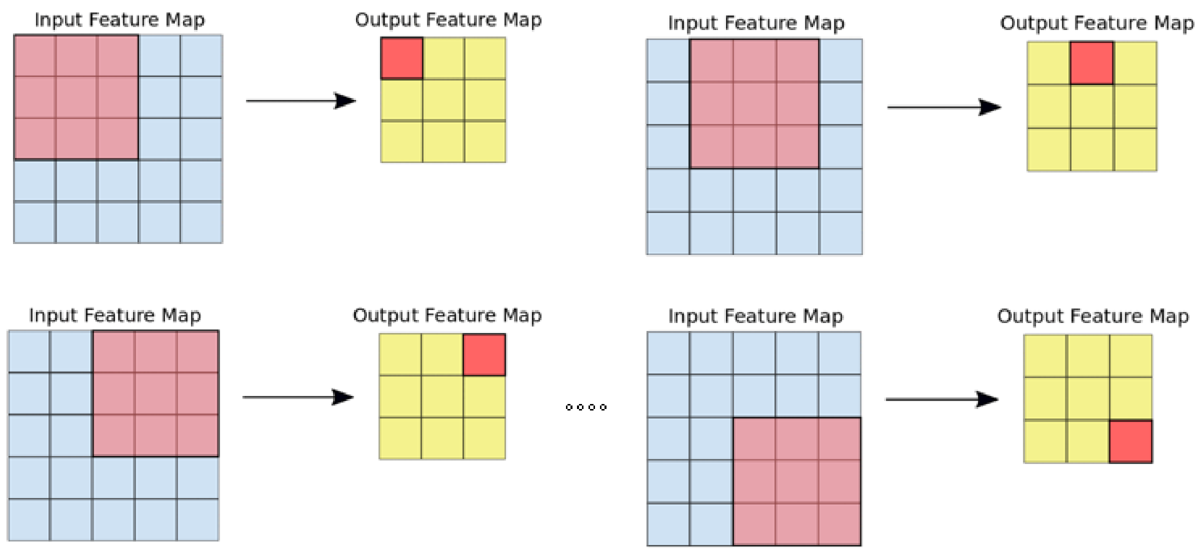

Figure 4: A 3x3 convolution of depth 1 performed over a 5x5 input feature map, also of depth 1. There are nine possible 3x3 locations to extract tiles from the 5x5 feature map, so this convolution produces a 3x3 output feature map (Google Developer 2018).

For each spatial position, the CNN performs element-wise multiplication of the convolutional filter and the input feature map (see figure 5) and then sums all the elements of the resulting matrix to get a single value (see figure 6). Each of these resulting values for every spatial position is then output in the output feature map (see figure 6).

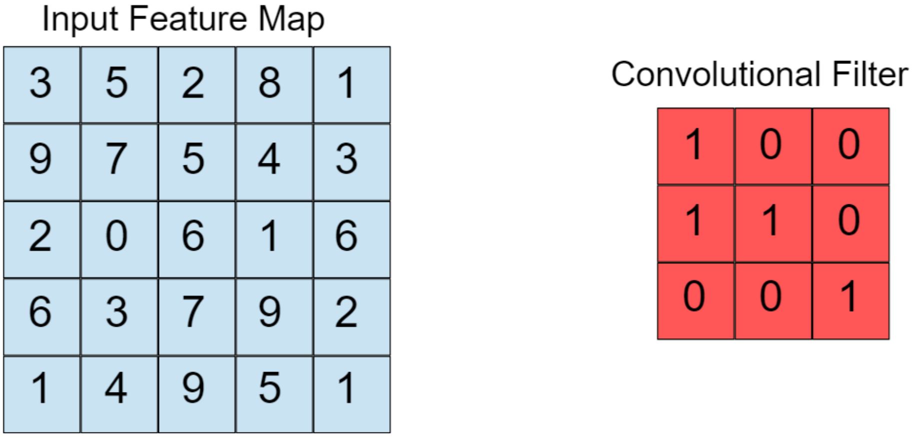

Figure 5: Left: A 5x5 input feature map (depth 1). Right: a 3x3 convolution (depth 1) (Google Developers 2018).

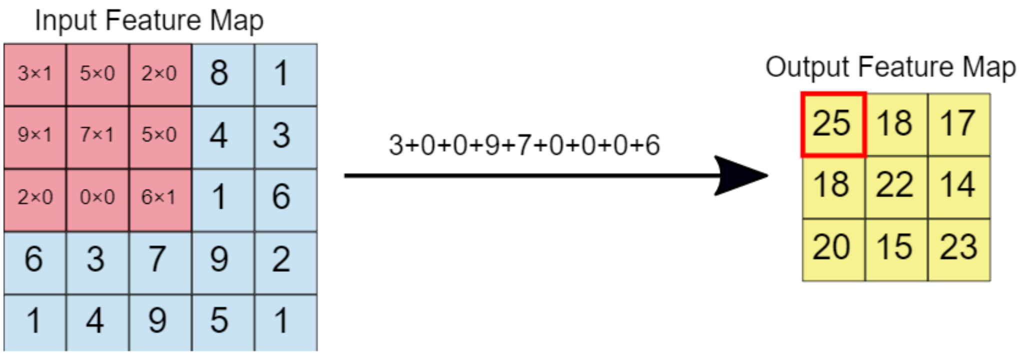

Figure 6: Left: The 3x3 convolution is performed on the 5x5 input feature map. Right: the resulting convolved feature (Google Developers 2018).

During training, the CNN optimises values for the filter matrices through the backpropagation[1] procedure, enabling it to extract meaningful features (textures, edges, shapes) from the input feature map (Google Developers 2018). The number of extractable features is dependent on the depth of the output feature map (number of filters applied to the input). In practice, engineers aim to construct networks that can extract necessary features for accurate image

[1] Backpropagation is a neural network terminology for minimising the cost function for non-linear problems. This will not be expanded upon to stay within the scope of the project since it requires pre-requisite understanding in supervised learning. Backpropagation is covered in Andrew Ng (2019) Machine Learning Course, Week 5. Pre-requisite requirements are covered in the previous weeks' lectures.

classification with a minimal number of filters. A network with fewer filters lowers overall training time as filters are computationally expensive. Furthermore, each filter added to the network provides less incremental value than the previous one (Google Developers 2018).

1.3.1.2.2 Non-linearity

A linear problem in ML is a mathematical problem that can be fitted by a line to predict (regression problem) or classify (classification problem) (Google Developers 2018). A typical example of a linear problem would be predicting house prices given the size of the houses, a regression problem or separate emails received into spam or not spam, a classification problem (Ng 2019).

Traditionally, linear models with feature crosses have been an efficient way to train on massive-scale datasets (Google Developers 2018). However, the issue arises when a problem consists of a high number of features (a non-linear problem) for a linear model to solve thus, brought forward the use of neural networks.

For nonlinear problems, the use of a neural network allows direct introduction of non-linearity to the algorithm by adding a nonlinear function (activation function)[2] to each node in the hidden layer (Google Developers 2018). Adding non-linearities to the hidden layer and stacking it introduces complexity to the learning pipeline allowing each layer to learn a more complex and higher-level function over the raw inputs (Google Developers 2018).

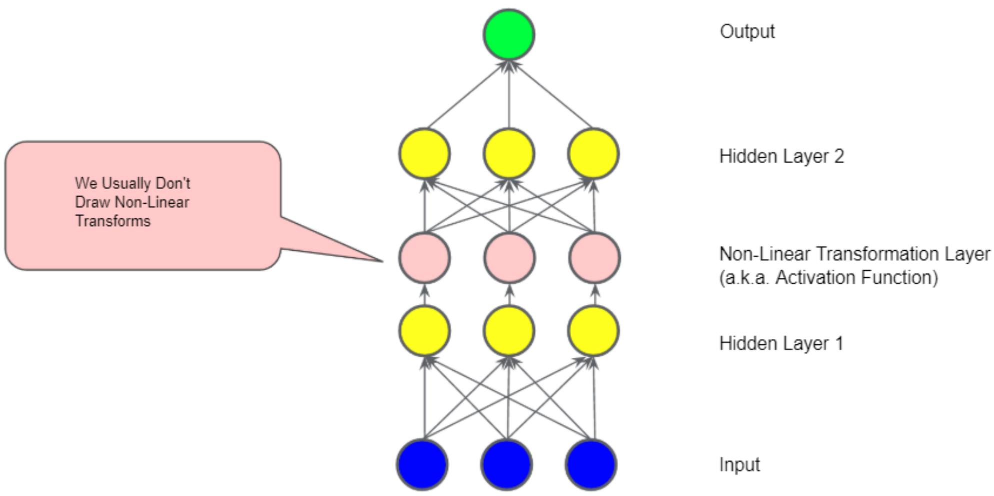

Figure 7: Non-Linear Transformation Layer (Google Developers 2018)

[2] Further explanation of activation function is avoided for the same reason as backpropagation. More information about the topic is available in Week 4 lecture of Machine Learning Course by Andrew Ng (2019).

1.3.1.2.2.1 Common activation function

Activation function (non-linearity) takes a single number and perform a certain fixed mathematical operation on it. In practice, several activation functions that are commonly used, such as the sigmoid and ReLU activation function.

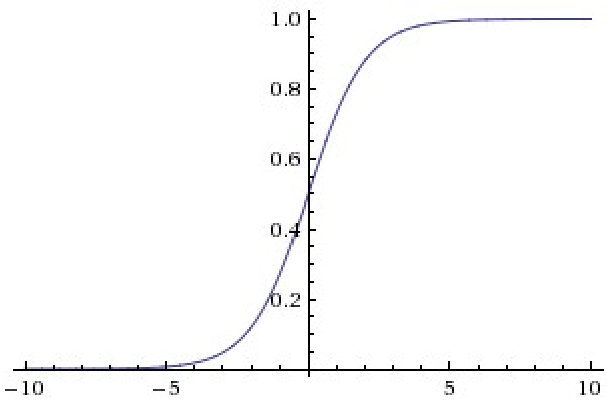

Figure 8: Graph of Sigmoid Activation Function (Li *et al.* 2018)

The sigmoid activation function (mathematically below) takes a real-valued number and converts it into a range between zero and one (Google Developers 2018) where large negative numbers become zero and large positive numbers become one (Li *et al.* 2018).

$$f(x) = \frac{1}{1 + e^{-x}}$$

Traditionally, the sigmoid activation function has seen frequent use because of its interpretation of the firing rate of a neuron, with zero for not firing and one as fully saturated firing (Li *et al.* 2018). However, the sigmoid non-linearity has recently fallen out of favour and it is rarely ever used because it saturates and kills gradients, and its outputs are not zero-centred (Li *et al.* 2018).

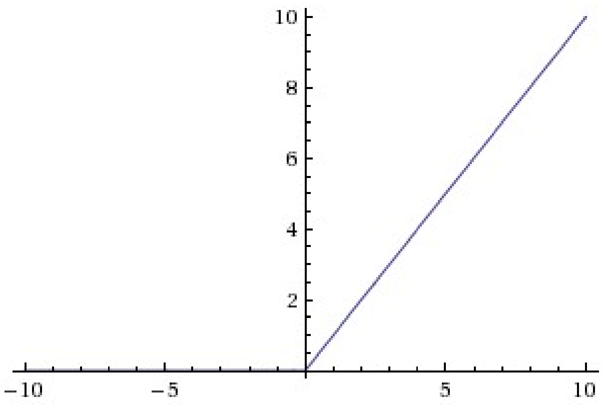

Figure 9: Graph of ReLU Activation Function (Li *et al.* 2018)

The Rectified Linear Unit (ReLU) shifts any input value less than zero to zero and input value equal or higher than zero as the original (mathematically as below).

$$f(x) = \max\,(0, x)$$

ReLU activation function is a popular choice for practice in the last few years because of its inexpensive mathematical operations (Li *et al.* 2018) and its ability to greatly accelerates the convergence of stochastic gradient descent compared to function such as sigmoid/tanh (Krizhevsky *et al.* 2012). A drawback of ReLU is its fragility during training. If the learning rate is set improperly (mostly too high), the gradient flowing through a ReLU neuron could cause the weights to update in a way that causes the neuron to prevent a portion network from updating (Li *et al.* 2018).

1.3.1.2.3 Pooling

Pooling function is to downsample the convolved feature to save on processing time and reducing the number of dimensions of the feature map hence control overfitting while preserving the most critical feature information (Google Developers 2018). The pooling layer operates independently on every depth slice of the input and resizes it spatially (Li *et al.* 2018). A common algorithm used for the pooling process is max pooling.

Max pooling operates like convolution where the filter slides over the feature map and extracting the maximum value from the local receptive fields then output the maximum value to a new feature map, and discard all other values (see figure below) (Google Developers 2018).

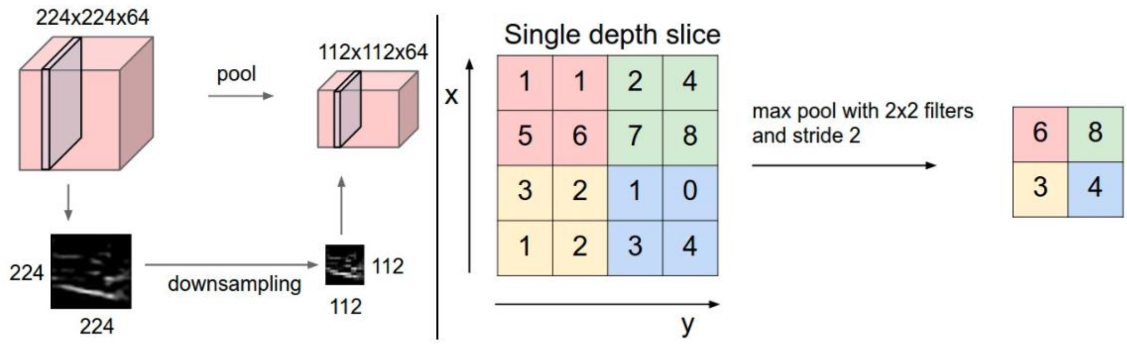

Figure 10: Pooling layer downsample the volume spatially, independently in each depth slice of the input volume. ***Left:*** *In this example, the input volume of size [224x224x64] is pooled with filter size 2, stride 2 into output volume of size [112x112x64]. Notice that the volume depth is preserved.* ***Right:*** *Max pooling used for downsampling, shown with a stride of 2 and a 2x2 filter extracting 4 numbers (Li et al. 2018).*

Fully Connected Layers

Generally, a CNN can be separated into a feature learning part and a classification part.

The feature learning layers of a CNN have neurons arranged in the same manner as the input image; however, the depth of the layer is the number of filters applied. The network performs a series of convolution and pooling operations to detect features from the input (previously covered) where each layer transforms the 3D input volume to a 3D output volume of neuron activations (see figure 11) (Li *et al*. 2018).

The classification part may consist of one or more fully connected layers that serve as a classifier on the features extracted by the convolutions (see figure 11) (Google Developers 2018). Noted, when there are two or more layers are “fully connected”, every node in the first layer are connected to every node in the second layer (Google Developers 2018). The final fully connected layer usually contains a SoftMax activation function which outputs the probability for each of the classification labels, same as an RNN (Google Developers 2018).

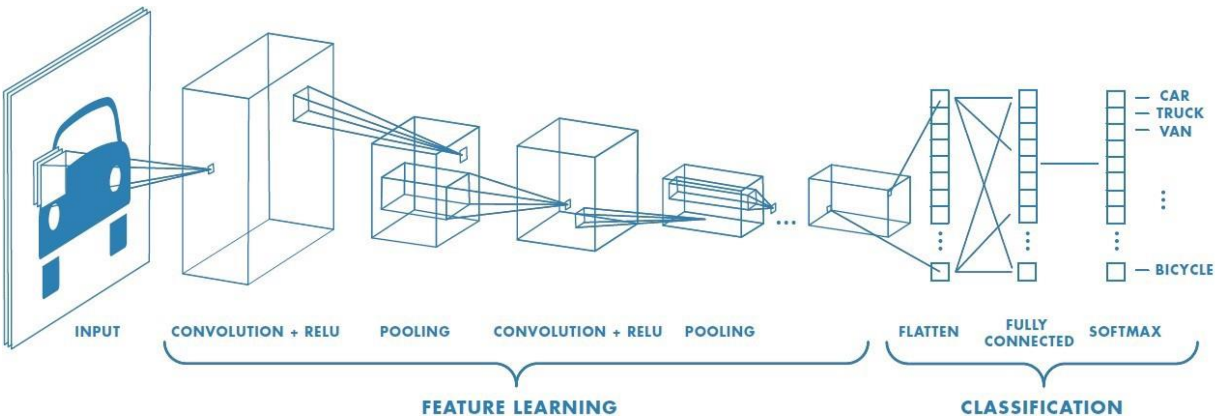

Figure 11: Example of a CNN separated into feature learning layer and classification layer (Patel and Pingel 2017)

1.4 Reviewing relevant researches

The following review of literature explores recent approaches used in image recognition processes to support medical diagnostics from CXR readings.

In 2015, Bar and colleagues explore the ability of convolutional neural network (CNN) learned from a non-medical dataset to identify different types of pathologies in CXR. This is achieved by pre-train the CNN on ImageNet (Deng *et al.* 2009) (a large scale real-life and non-medical image database). The result shows that categorisation rates can be slightly improved by combining features extracted from the CNN and the GIST descriptor (Oliva & Torralba 2001) (a common low-level visual feature that is optimal for the task of object categorisation). The result obtained an area under the curve (AUC) of 0.87-0.94 for different pathologies thus is the first-of-its-kind experiments that demonstrated the feasibility of detecting thorax diseases in CXR using deep learning approaches based on non-medical learning.

Sharma *et al.* (2017) present a novel approach for detecting the presence of pneumonia clouds in CXR by using only image processing techniques. The authors used Python and OpenCV to develop an indigenous algorithm for cropping and extraction of the lung region from the images and Otsu thresholding image processing-based method to segregate the health part of the lung from pneumonia infected cloudy regions. The approach was tested on 40 analogue CXR instead of an online dataset to match the rural scenario situations. Their experiment was able to identify the lung region by rib cage boundary identification and segregate the pneumonia cloud from the healthy lung in the lung area. However, the results were not all favourable as pneumonia clouds are not visible in the image of the lung after Otsu thresholding. The author concluded their paper with hope for better image thresholding with other methods they are working on.

In 2017, Rajpurkar and team developed an algorithm named CheXNet that can detect pneumonia from CXRs at a level exceeding practising radiologists. The algorithm inputs a chest X-ray image and outputs the probability of pneumonia along with a heatmap localizing the areas of the image most indicative of pneumonia. CheXNet used a 121-layer Dense Convolutional Network (Huang *et al.* 2017) trained on the ChestX-ray14 dataset (Wang *et al.* 2017) and batch normalisation (Ioffe & Szegedy 2015) to make the optimization of such a deep network tractable. The AUC of pneumonia on the Chest-Xray14 dataset was 76.8%, comparing to 63.3%, 71.3% from Wang *et al.* (2017) and Yao *et al.* (2017) respectively. When comparing to radiologist performance on the F1 metric, CheXNet exceeds the radiologist performance with a score of 0.435 (95% CI 0.387, 0.481), higher than the radiologist average of 0.387 (95% CI 0.330, 0.442).

In 2018, Guan *et al.* proposed a three-branch attention guided convolution neural network (AG-CNN) that addressed two issues that they identified with thorax disease classification. Firstly, a thorax disease usually happens in (small) localized areas which are disease-specific. Training CNNs using global image may be affected by the (excessive) irrelevant noisy areas. Secondly, due to the poor alignment of some CXR images, the existence of irregular borders hinders the network performance. The AG-CNN addresses the first problem by learning from disease-specific regions to avoid noise and improve alignment and the second problem by integrating a global branch to compensate the lost discriminative cues by the local branch. Specifically, the algorithm first learns a global CNN branch using global images. Then, guided by the attention heat map generated from the global branch, it inferences a mask to crop a discriminative region from the global image. The local region is used for training a local CNN branch and the last pooling layers of both the global and local branches are concatenate for fine-tuning the fusion branch. With their experiment conducted on the ChestX-ray14 dataset (Wang *et al.* 2017), their project reported a strong global baseline producing an average AUC of 0.841 with ResNet50 as the backbone. After combining the local cues with global information, AG-CNN improves the average AUC to 0.868. While DenseNet-121 is used, the average AUC achieves 0.871, which is a new state of the art in the community in 2018.

2 Project Overview

2.1 *Project Objective*

The objective of this project is to *prototype a deep learning algorithm to detect visual signals of pneumonia infection* by detecting lung opacities in chest radiographs. The goal of this project is to contribute to computer-aided detection technology in the medical field to reduce the stress on specialists when making diagnoses for pneumonia.

2.2 *Project Scope*

2.2.1 Inclusion

In summary, the project scope includes:

- Explore and select a suitable CXR dataset for pneumonia identification
- Classify chest radiographs of pneumonia vs normal
  - Explore image classification methods
  - Adopt appropriate training methods for the project
  - Produce an image classification model to identify pneumonia in CXR

2.2.2 Exclusion

The project scope shall exclude the following:

- Classify CXR of pneumonia vs normal vs other thorax diseases
- Locate specific area of pneumonia

2.3 *Report Structure*

The main section of this report separates into three sections: Data, Model and Experiment. This separation simulates the basic structure of a classification algorithm program: Data, Model and Analysis.

The three sections of the report further breakdown into two/three sections covering the analysis and selection of each section and theories to assist with understanding these decisions.

2.4 Resources

2.4.1 Hardware

This project does not require any specific hardware as its utilised Google Colaboratory, Google Colab in short. Google Colab is a cloud-based Jupyter Notebook environment which can execute code on Google's cloud servers, thus, leverage the power of Google hardware, including GPUs and TPUs, regardless of the power of the local machine.

Access: https://colab.research.google.com/

2.4.2 Software

The programming language used for the project is Python as it is widely used in the data science community and built into Google Colab. Keras is used on top of Tensorflow to assist with modelling of the neural network.

Programming Language: Python

Framework: Keras and Tensorflow

2.4.3 Dataset

The ChestX-ray14 (Wang *et al.* 2017) dataset and the Mendeley CXR (Kermany *et al.* 2018) dataset are both previewed for the project. After evaluation, the Mendeley CXR (Kermany *et al.* 2018) dataset is selected for experimentation. Further information about these datasets and the dataset selection is available in the data section of the report.

ChestX-ray14 Dataset (Wang *et al.* 2017)

Access: https://nihcc.app.box.com/v/ChestXray-NIHCC

Mendeley Chest X-ray Dataset (Kermany *et al.* 2018)

Access: https://data.mendeley.com/datasets/rscbjbr9sj/3

3 Data

3.1 Theories

The section below covers fundamental theories to aid in understanding the selection of the dataset including strategies to improve the data quality before the training process. Most of the strategy listed are carried out in the respective experiments as listed in table 1, parameter setup of the model selection section and its impact is analysed in the experiment analyses section. To see these techniques are applied, view the respective appendices per table 1.

3.1.1 Data Preprocessing

Pre-processing data is a common first step in the deep learning workflow to prepare raw data in a format that the network can accept (MathWorks 2019a). Data for machine learning may be view in three stages: raw data, prepared data, and engineered features.

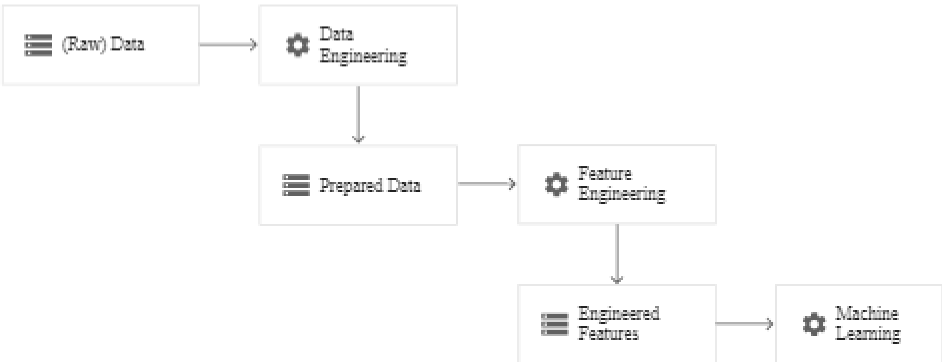

Figure 12: The flow of data from raw data to prepared data to engineered features to machine learning (Google Developers 2019)

Raw data are data in its source form, without any prior preparation for ML (Google Developers 2019). Prepared data refers to a dataset in a form ready for the ML task at hand. Data has been aggregated, summarised and irrelevant data are dropped and filtered out (Google Developers 2019). Engineered features refer to a dataset with tuned features for the model (Google Developers 2019). The section below expands upon the feature engineering process. The data engineering process is not further studied because it is out of scope and the datasets explored in this project are previously labelled, screened and filtered by professionals for machine learning application.

Feature engineering is covered in this project for two main reasons. Firstly, to potentially lower the training time and secondly, to increase the diversity of data available and potentially improve the network mapping capability (further analysed in the experiment analyses section).

The speed of gradient descent directly impacts the training time (Ng 2019). Gradient descent can speed up by having each of the input values in roughly the same range, ideally between -1 to 1 or -0.5 to 0.5 (further explained in Week 2 lecture by Ng 2019). Two techniques applicable to speed up gradient descent are feature scaling and mean normalisation.

3.1.1.1 Feature scaling (Rescaling)

Feature scaling is carried out by dividing the input values by the range (maximum value minus minimum value) of the input variable, thus, resulting in a new range of 1 (Ng 2019). For images as input, the RGB coefficients have a range of 0 to 255, which can be rescaled to values between 0 to 1 by scaling with a factor of 1/255 (Chollet 2016).

3.1.1.2 Mean normalisation

Mean normalization involves divide each dimension by its standard deviation, once it has been zero-centred (Li *et al.* 2018). Zero-centred can be achieved by subtracting the average value for an input variable from the values for that input variable resulting in a new average value of zero for the input variable (Ng 2019). Mathematically as follow:

$x_i = \frac{x_i - u_i}{s_i}$; *where x_i is the input value, u_i is the average of all the values for feature (i) s_i is the standard deviation.*

Normalisation should only be applied when different input features have different scales or units. For images, the relative scales of pixels are already approximately equal (and in a range from 0 to 255), so it is not strictly necessary to perform normalisation (Li et al. 2018)

3.1.1.3 Data augmentation

Data augmentation is a strategy that enables practitioners to significantly increase the diversity of data available for training models without collecting new data. This strategy lowers the chance of the model seeing the same image multiple times to potentially prevent overfitting and helps the model generalises better, as previously mentioned (Chollet 2016). Data augmentation techniques such as cropping, padding, and horizontal flipping are commonly used to train large neural networks (Ho *et al.* 2019a).

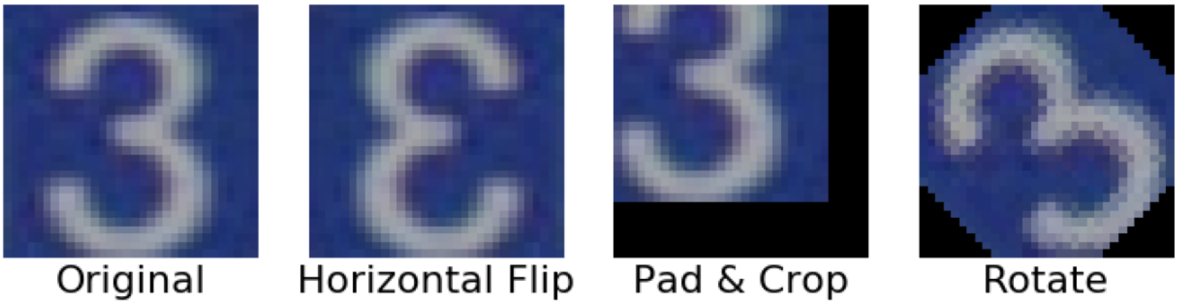

Figure 13: Example of Data Augmentation Techniques on an Image (Ho et al. 2019b)

3.1.1.4 Class balancing

In a classification task where the task output one of two mutually exclusive classes (binary classification), if the labels for the two classes have significantly different frequencies, then this is a class-imbalanced problem.

For example, a pet dataset which has 0.1 cat samples and 0.9 dog samples is an imbalance. A sample disease data set which has 0.51 examples of negative labels and 0.49 examples of positive labels is not a class-imbalanced problem (Google Developers 2019)

When the dataset is imbalanced, the model will be biased towards the more popular class during the training process, which can be unfavourable in specific scenarios. Nevertheless, this could be prevented by applying standard techniques such as balancing the dataset with a weighted cost function or oversampling (Tensorflow 2019).

3.2 About the Data

During the preliminary research, the ChestX-ray14 dataset (Wang *et al.* 2017) and the Mendeley CXR dataset (Kermany *et al.* 2018) were both promising datasets available publicly for research purposes.

3.2.1.1 ChestX-ray14 Dataset (Wang et al. 2017)

The ChestX-ray14 dataset (Wang *et al.* 2017) comprises of 112,120 frontal-view X-ray images of 30,805 unique patients mined from associated radiological reports using natural language processing with text-mined fourteen disease image labels. The labels are expected to be more than 90% accurate, which is suitable for weakly-supervised learning. Out of the total images, 51,708 images contain one or more pathologies and the remaining 60,412 images do not contain the listed 14 diseases findings. The fourteen diseases included are Atelectasis, Consolidation, Infiltration, Pneumothorax, Edema, Emphysema, Fibrosis, Effusion, Pneumonia, Pleural thickening, Cardiomegaly, Nodule, Mass and Hernia (Wang *et al.* 2017).

3.2.1.2 The Mendeley CXR Dataset (Kermany et al. 2018)

The Mendeley CXR dataset is part of the "Large Dataset of Labeled Optical Coherence Tomography (OCT) and Chest X-Ray Images" by Kermany *et al.* (2018). The CXR dataset consisted of 5,863 frontal chest x-ray images separated into two categories (Pneumonia/Normal). These images were selected from retrospective cohorts of paediatric patients of one to five years old from Guangzhou Women and Children's Medical Center, Guangzhou, where all chest x-ray imaging was performed as part of patients' routine clinical care. All CXR were initially screened for quality control by removing all low quality or unreadable scans then graded by two expert physicians. The evaluation set was also checked by a third expert before released to account for any grading errors (Kermany *et al.* 2018).

3.3 Dataset Selection

The ChestX-ray14 dataset has a varied number of disease database and a high amount of data which significantly reduces the risk of overfitting and underfitting (to be discussed in the model section). Contrarily, the high number of data and variation can be disadvantageous as it increases training and validation time and data preparation difficulty.

The Mendeley CXR dataset is a small dataset (5,863 images comparing to 112,120 images of ChestX-ray14 dataset) that focus only on pneumonia. When working with a small dataset, overfitting/underfitting will be a problem, but there are a few key advantages. The images in the Mendeley CXR dataset are organised into two categories, pneumonia and normal, which meet the exact requirement of the project, thus reduces the time and work required for data preparation. Additionally, the small data set reduces the time required for model training and validation. Another benefit is that the need for consideration of dataset's labelling error can be eliminated since experts previously conducted rigorous quality control.

After reviewing both datasets, the Mendeley CXR dataset is selected for this project as its advantages are held in higher value due to concern for time and technical capability.

3.4 Selected Dataset Analysis

The Mendeley CXR dataset certainly has its advantages, however, to proceed with the project efficiently, further investigation of its potential problems and possible solutions are discussed below.

3.4.1.1 Dataset size

The dataset has approximately 6,000 images; this may be problematic when training a deep learning model as deep learning is a process that relies heavily on the amount of data (Launchbury 2017). The small dataset can create problems such as overfitting (the model unable to generalise), outliers become much more dangerous and noise (random fluctuations in feature values) becomes a real issue (Deeb 2015). The next section (Model) will further discuss and analyse these issues.

3.4.1.2 Data Imbalance

The dataset contains 1,583 (27%) normal and 4,273 (73%) pneumonia images in total. The data will be biased toward the pneumonia class, but this could be prevented by balancing the class as previously mentioned in the data theories part. The effect class weight balancing for our project will be further analysed in the experiment section.

4 Model

4.1 Theories

4.1.1 Overfitting and Underfitting

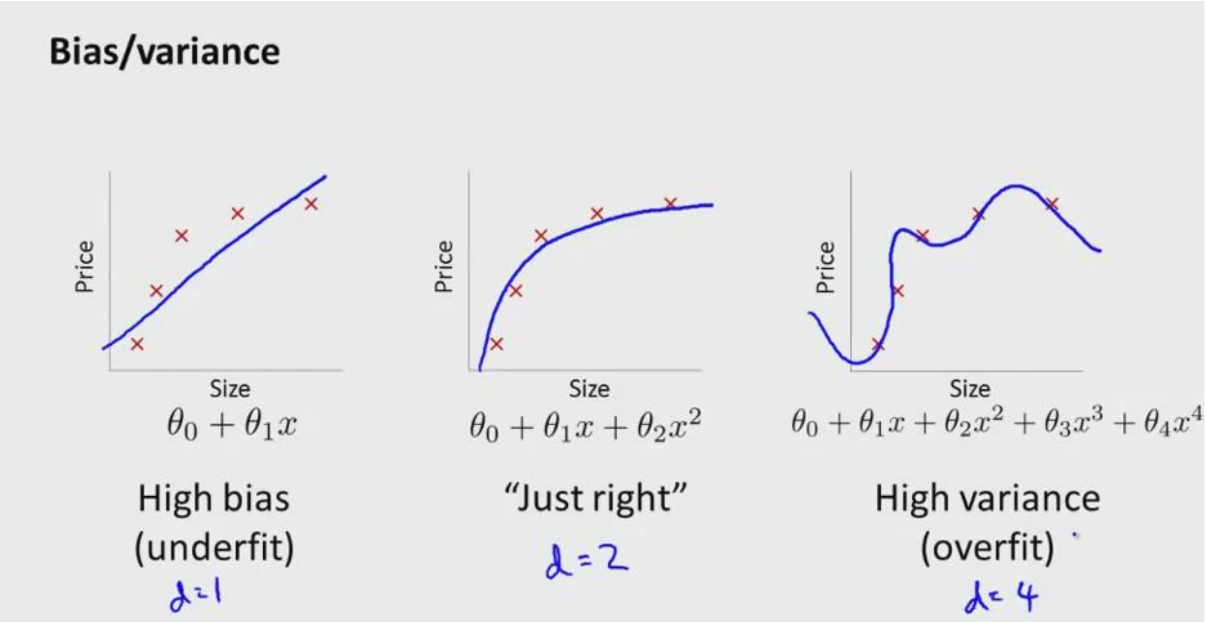

Figure 14: Example of Model fits to Data (Ng 2019)

Underfitting, or high bias, is when the model maps poorly to the trend of the data. This may happen because the model is too simple, is over-regularised, uses too few features, or has not been trained long enough. Hence, the network has not learned the relevant patterns in the training data (Ng 2019).

At the other extreme, *overfitting*, or high variance, is when a model fits the available data but does not generalise well to predict new data. It is usually caused by over-training the model or using a complicated model that creates a lot of unnecessary curves and angles unrelated to the data (Ng 2019).

In practice, the most desired outcome is to minimise both bias and variance (e.g build a model which not only fits the training data well but also generalises well on test/validation data). The best solution to prevent overfitting is to use more complete training data (Tensorflow 2019). Other methods such as regularisation, data augmentation, batch normalisation, reducing the network capacity or transfer learning are commonly used when obtaining more training data is unfeasible (Tensorflow 2019; Li *et al.* 2018).

4.1.2 Regularization

4.1.2.1 Weight Regularisation

Overfitting tends to happen when the learning model is over-complicated; this means that "simple models" where the distribution of parameter values has less entropy or a model with fewer parameters are less likely to overfit (Tensorflow 2019). From this understanding, a common way to mitigate overfitting is to put constraints on the complexity of a neural network by forcing its weights only to take small values, thus, the distribution of weight values becomes more "regular" (Tensorflow 2019). In practice, this method is known as "weight regularisation" and can be carried out by adding to the loss function of the network a cost associated with having large weights (Tensorflow 2019). This method comes in two forms.

4.1.2.1.1 L1 Regularisation

In L1 regularisation, the cost is added proportionally to the absolute value of the weights coefficient, also known as the "L1 norm" of the weights (Tensorflow 2019).

4.1.2.1.2 L2 Regularisation

In L2 regularisation, the cost is added proportionally to the square of the value of the weights coefficient, also known as the squared "L2 norm" of the weights (Tensorflow 2019). In the context of neural networks, L2 regularisation may be named weight decay.

4.1.2.2 Dropout

Dropout is an extremely effective, simple and commonly used regularisation technique for NNs by Srivastava *et al.* 2014. The intuition behind dropout is that individual nodes in NN cannot rely on the output of the other nodes; each node must output features that useful on their own (Tensorflow 2019).

During training, dropout applied to a layer will randomly "drop out" some output features of the layer (Tensorflow 2019) (see figure below). This can be interpreted as a sample of a NN within a full NN and only update the parameters of the sampled NN based on the input data (Li *et al.* 2018). During testing, drop out is not applied and the layer's output values are scaled to an averaged prediction across the exponentially-sized ensemble of all sub-networks (Li *et al.* 2018; Tensorflow 2019).

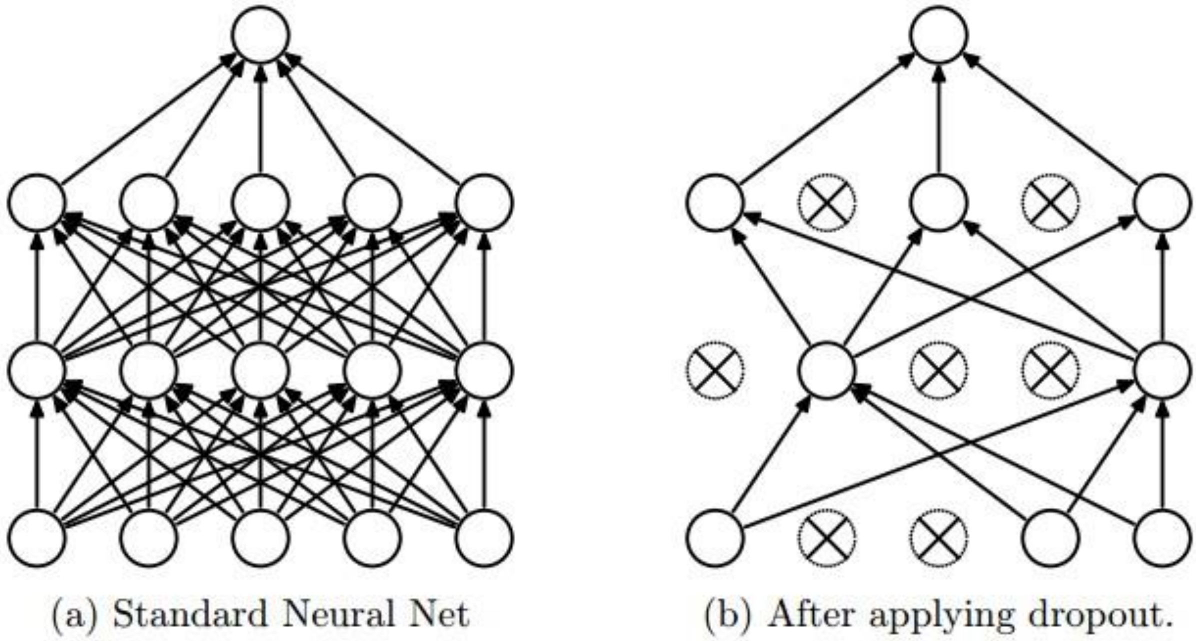

Figure 15: Regularisation Technique - Dropout (Li et al. 2018)

4.1.3 Loss Functions

A loss function may be interpreted as data loss, which is a supervised learning problem measures the compatibility between a prediction (e.g. the class scores in classification) and the ground truth label (Li *et al.* 2018). The data loss takes the form of an average over the data losses for every individual example. For classification problems, the two commonly seen cost functions are the SVM (e.g. the Weston Watkins formulation) and the SoftMax classifier that uses the cross-entropy loss (Li *et al.* 2018).

4.1.4 Optimisers

By looking at the loss function job as a function that gives value data loss in a model. The goal an optimiser is to decide how much to change in each parameter to minimise the loss function (Li *et al.* 2018; Tensorflow 2019c). Optimisation for deep networks is currently a very active area of research, even tuning the learning rates is an expensive process with experts spending many hours into devising methods that can adaptively tune the learning rates, and even do so per parameter (Li *et al.* 2018). In practice, adaptive learning methods such as SGD, RMSprop and Adam are commonly used with many of these methods may require modification of other hyperparameter settings. However, they are reliable for a broader range of hyperparameter values in comparison to the raw learning rate (Keras 2019).

4.1.5 Training methods

4.1.5.1 Training from scratch

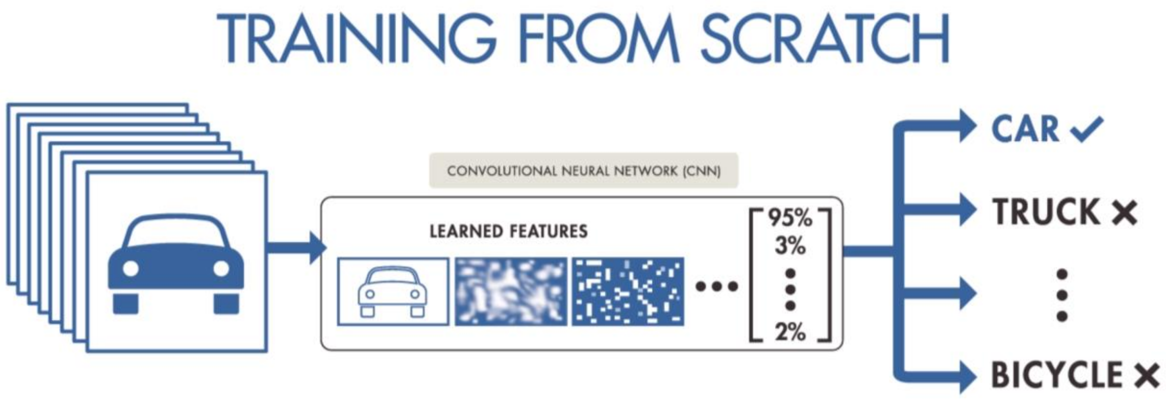

Figure 16: Training from Scratch (Patel and Pingel 2017)

Training a CNN from scratch with random initialization is highly accurate but also the most challenging method. Training a model from scratch requires a massive number of labelled images, significant computational resources and time (Patel and Pingel 2017).

4.1.5.2 Transfer learning

In practice, it is common to use a pre-trained model or transfer learning to customise a pre-trained model to a given task (Li *et al.* 2018). A pre-trained model is a saved network that has been trained on a very large dataset (e.g. ImageNet, which contains 1.2 million images with 1000 categories). The intuition behind transfer learning is that if a model is trained on a large and general enough dataset, this model will serve effectively as a generic model for other datasets with similar features (Li *et al.* 2018). Two popular strategies for transfer learning in image classification problems are as follows:

4.1.5.2.1 Feature extraction

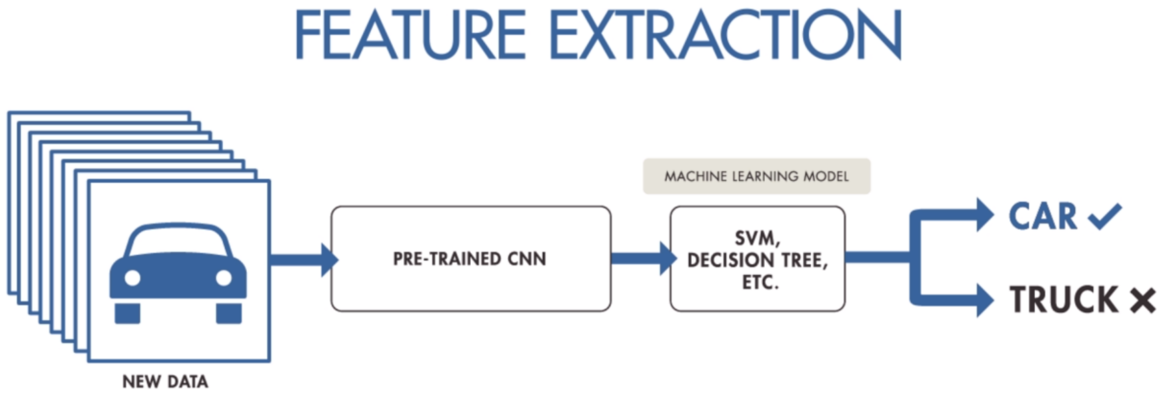

Figure 17: Transfer Learning - Feature extraction (Patel and Pingel 2017)

Feature extraction involves taking a CNN pre-trained on a large dataset, remove its last fully-connected layer, then reuse the rest of the CNN as a fixed feature extractor for the new dataset (Li *et al.* 2018). A linear classifier (e.g SVM or SoftMax) replaces the last FC layer and trained for the new dataset (see figure above).

4.1.5.2.2 Fine-tuning

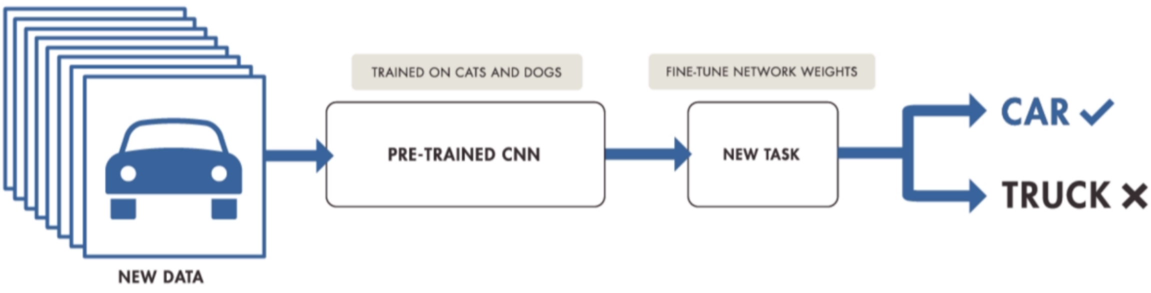

Figure 18: Transfer Learning - Fine tuning (Patel and Pingel 2017)

The other strategy is to replace and retrain certain layers of the network if necessary and fine-tune the weights of the pre-trained network by continuing the backpropagation (Li *et al.* 2018). It is possible to fine-tune all the layers of the CNN; however, fine-tuning earlier layers of the network may increase overfitting. The main reason is that convolution layers in the feature learning part contain more generic features (e.g. edge detectors or colour blob detectors) and the later layers (classification part) of the CNN are more specific to the details of the classes contained in the original dataset (Li *et al.* 2018).

4.1.5.2.3 Constraints

The use of a pre-trained network may be constraining in term of architectural availability and adaptation for the dataset of choice. Removal of the convolutional layers of the pre-trained network may make transfer learning redundant. However, modification of fully-connected layer, fine-tuning some higher-level portion of the network or pre-train the network with images of different spatial size is acceptable (Li *et al.* 2018).

4.1.5.2.4 Learning Rate

The learning rate of an optimizer algorithm dictates its ability to learn over the number of iterations. When the learning rate is too small, the algorithm may be slow to converge. However, if the learning rate is too large, the algorithm may not decrease on every iteration and thus may not converge (Ng 2019).

When using transfer learning, it is common to use a smaller learning rate for CNN weights that are being fine-tuned. This is because the pre-trained CNN weights are expected to be relatively good; thus, a smaller learning rate prevents the weights from distorting uncontrollably (Li *et al.* 2018).

4.2 Model Selection

Rather than architecting a CNN from scratch, this project's models are prototyped based on existing neural networks architecture with proven success for computer-vision related tasks. The models were selected based on three criteria: depth, accuracy, and their availability on Keras (the framework used in this project).

Figure 20 below presents eighteen models available on Keras with top 5% accuracy performance on the ImageNet validation test (Deng *et al.* 2009). The following four out of eighteen networks are selected to undertake the experiment.

1. VGG16 (Simonyan & Zisserman 2014)
2. ResNet50V2 (He *et al.* 2016b)
3. NasNetMobile (Zoph & Le 2016)
4. InceptionResNetV2 (Szegedy *et al.* 2017)

VGG16 (Simonyan & Zisserman 2014) and ResNet50V2 is selected because of their relatively shallow depth in comparison the other CNN on the list (see figure 21). NasNetMobile (Zoph & Le 2016) is selected because of its unique ability to optimize its architecture depending on the dataset. InceptionResNetV2 (Szegedy *et al.* 2017) is selected because of our curiosity on the performance of a deep network on a relatively small dataset. More information about each of the selected model are available in the next section.

VGG16 is selected as our main model as it is the smallest CNN available in Keras, a simpler network is less likely to overfit (Tensorflow 2019) and requires less computation power, thus has the potential to produce the best result and requires less time to train the model.

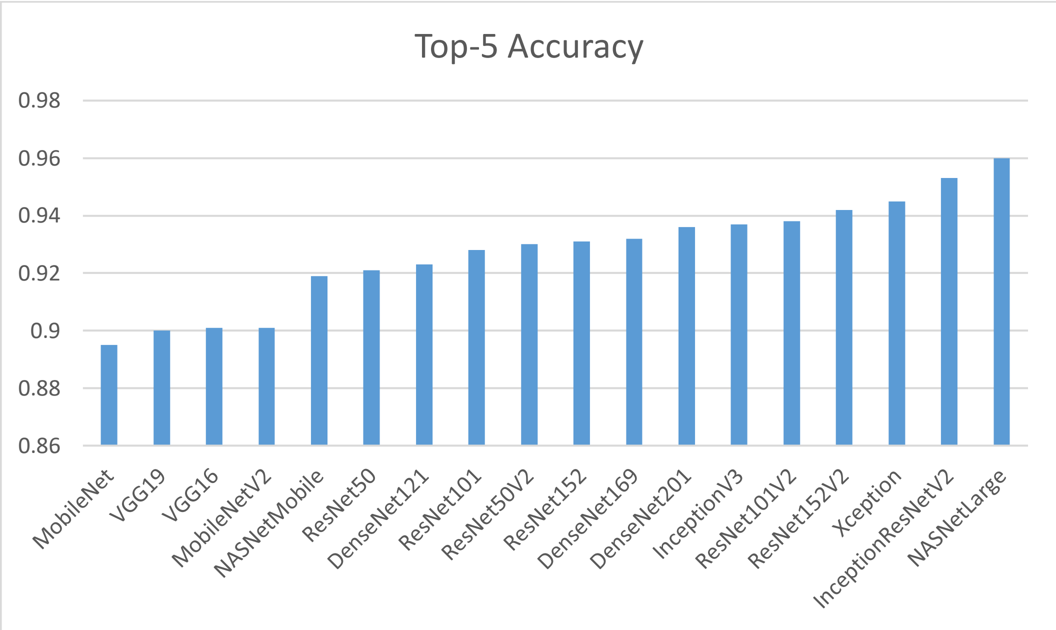

Figure 19: Comparison of CNN models with top 5% accuracy performance on the ImageNet validation dataset (Keras 2019)

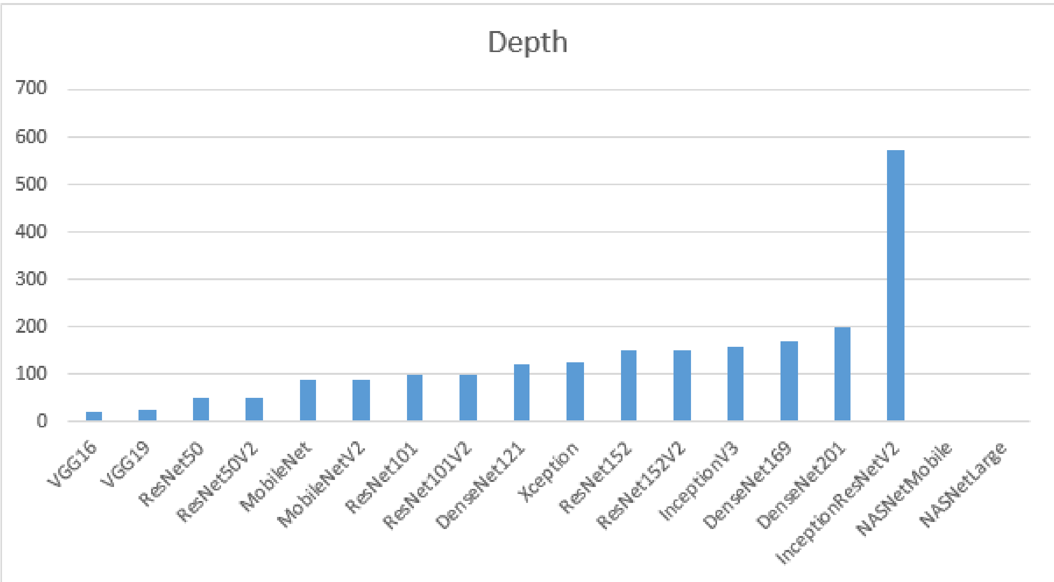

Figure 20: CNN models depth comparison

4.2.1 About the models

4.2.1.1 VGG16

VGG is a “very deep convolutional” networks developed by (Simonyan & Zisserman 2014) for largescale image classification. The model secured first and second places in the localisation and classification tracks respectively for the ImageNet Challenge 2014. The network has a depth up to 19 weight layers using an architecture with very small (3 x3) convolution filters (see figure below). This project will work with configuration D (see figure below) of the VGG16 network due to its availability on Keras. Further explanation about the training methods and modification to the model is available the experiment section of the project.

ConvNet Configuration					
A	A-LRN	B	C	D	E
11 weight layers	11 weight layers	13 weight layers	16 weight layers	16 weight layers	19 weight layers
input (224 × 224 RGB image)					
conv3-64	conv3-64 **LRN**	conv3-64 **conv3-64**	conv3-64 conv3-64	conv3-64 conv3-64	conv3-64 conv3-64
maxpool					
conv3-128	conv3-128	conv3-128 **conv3-128**	conv3-128 conv3-128	conv3-128 conv3-128	conv3-128 conv3-128
maxpool					
conv3-256 conv3-256	conv3-256 conv3-256	conv3-256 conv3-256	conv3-256 conv3-256 **conv1-256**	conv3-256 conv3-256 **conv3-256**	conv3-256 conv3-256 conv3-256 **conv3-256**
maxpool					
conv3-512 conv3-512	conv3-512 conv3-512	conv3-512 conv3-512	conv3-512 conv3-512 **conv1-512**	conv3-512 conv3-512 **conv3-512**	conv3-512 conv3-512 conv3-512 **conv3-512**
maxpool					
conv3-512 conv3-512	conv3-512 conv3-512	conv3-512 conv3-512	conv3-512 conv3-512 **conv1-512**	conv3-512 conv3-512 **conv3-512**	conv3-512 conv3-512 conv3-512 **conv3-512**
maxpool					
FC-4096					
FC-4096					
FC-1000					
soft-max					

Figure 21: VGG16 network architecture (Simonyan & Zisserman 2014)

4.2.1.2 ResNet50V2

Similar to the previously proposed model ResNet (He *et al.* 2016a), a deep learning network with a residual learning framework to ease the training of networks that are substantially deeper. ResNetV2 (He *et al.* 2016b) layers are reformulated as learning residual functions with reference to the layer inputs, instead of learning unreferenced functions. In addition, RestNetV2 improves generalisation and training by using methods such as skip-connections and after-addition activation when using identity mappings (He *et al.* 2016b).

On Keras, there is a variety of ResNet models but ResNet50V2 is selected for this project due to its relatively small size and renewed design. More implementation detail for this model is available in the experiment section.

4.2.1.3 NASNetMobile (Zoph & Le 2016)

NASNet (Zoph & Le 2016) is a method that learns the model architectures directly on the dataset of interest inspired by the recently proposed Neural Architecture Search (NAS) framework by Zoph and Le (2016), which uses a reinforcement learning search method to optimize architecture configuration. The problem with the application of NAS or any other search methods directly to a large dataset such as the ImageNet dataset (Deng *et al.* 2009) is computationally expensive. Therefore, the authors (NASNet) proposed to search for an architectural building block on a small dataset and then transfer the block to a larger dataset, named the “NASNet search space”.

The “NASNet search space” enable transferability by detaching the network architectural dependency from its depth and the size of input images. More concretely, all convolutional networks in the search space are composed of convolutional layers (or “cells”) with identical structure but different weights. Searching for the best convolutional architectures is therefore reduced to searching for the best cell structure (Zoph & Le 2016).

In their experiments, the Zoph and Le (2016) searched for the best "cell" on the CIFAR-10 dataset and then applied this cell to the ImageNet dataset by stacking together more copies of this cell, each with their parameters to design a convolutional architecture, named "NASNet architecture".

This project will use a more computationally constrained version of NASNet known as NASNetMobile (Zoph & Le 2016).

4.2.1.4 InceptionResNetV2 (Szegedy et al. 2017)

InceptionResNetV2 (Szegedy *et al.* 2017) is an architecture that combines residual connections introduced by He *et al.* (2016a) and Szegedy *et al.* (2016) Inception-v3 architecture. Residual inception networks (He *et al.* 2016a) outperform similar computationally expensive non-residual Inception networks by a thin margin. By training with residual connections accelerates the training of Inception networks significantly (Szegedy *et al.* 2017).

The architecture of InceptionResNetV2 (Szegedy *et al.* 2017) is summarised in the figure below. This quick view avoids detail analysis of InceptionResNetV2 since it is due to its complexity, thus lead the project out of scope. The authors work summarised as below.

- Inception-ResNet-v1: a hybrid Inception version that has a similar computational cost to Inception-v3 from Szegedy *et al.* (2016)
- Inception-ResNet-v2: a costlier hybrid Inception version with significantly improved recognition performance.
- Inception-v4: a pure Inception variant without residual connections with roughly the same recognition performance as Inception-ResNet-v2.

Inception-ResNet-v2 is selected to be experimented within this project because of its availability on Keras. More information about the model modification and setup is available in the experiment section of the report.

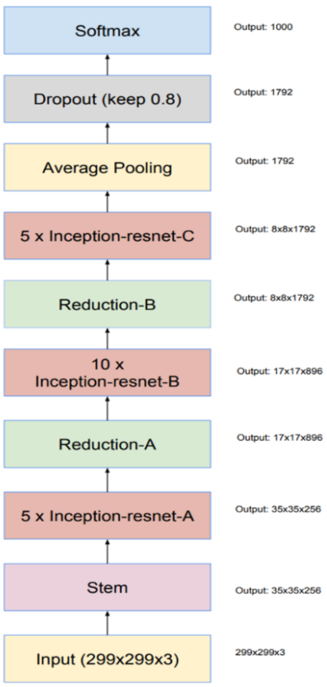

Figure 22: Schema for Inception-ResNet-v1 and InceptionResNet-v2 networks. (Szegedy et al. (2017)

5 Experiment

5.1 Theories

5.1.1 Analyse the Learning Process

There are multiple useful quantities that should be monitored during the training of a NN. These plots are the window into the training process and should be utilized to get intuitions about different hyperparameter settings and how they should be changed for more efficient learning (Li *et al.* 2018).

The x-axis of the plots below is in units of epochs, which measure how many times every example has been seen during training (e.g. one epoch means that every example has been seen once). It is preferable to track epochs rather than iterations since the number of iterations depends on the arbitrary setting of batch size (Li *et al.* 2018).

5.1.1.1 Loss function

The loss function evaluates the individual batches during the forward pass. The loss function graph is useful as its shape may provide information about the learning rate (see diagram below).

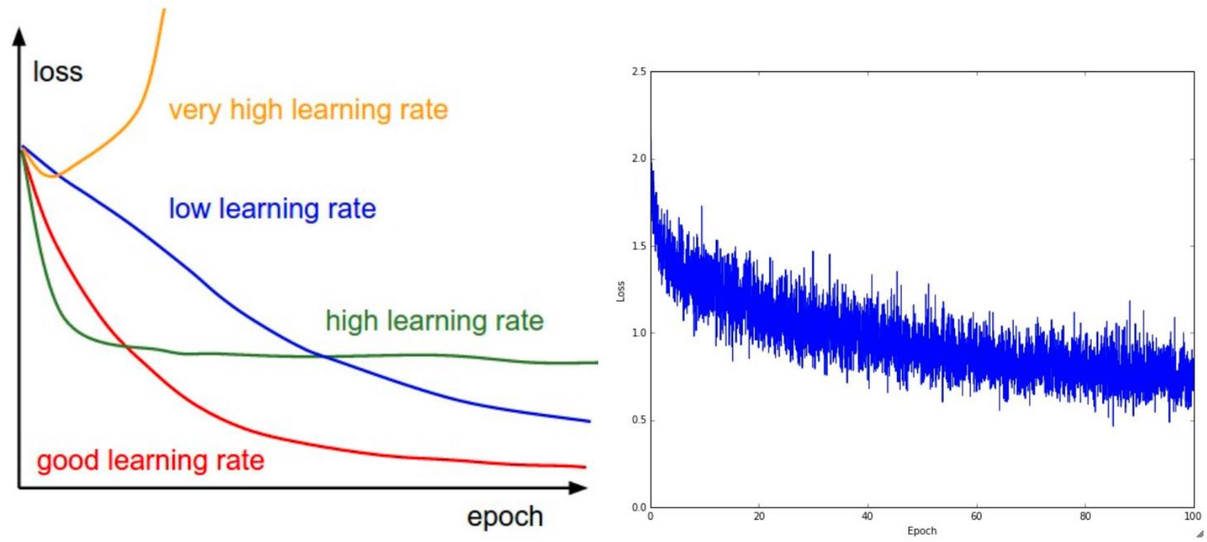

Figure 23: Example of loss function graph and possible interpretation (Li et al. 2018)

The left figure depicts the effects of different learning rates. Notice that with low learning rates, the improvements will be linear and with high learning rates, the loss over time will start to look more exponential. Higher learning rates will decay the loss faster but will be fixed at a higher value than possible (green line). This may be due to the high amount "energy" in the optimization; thus, the parameters are unable to settle in a sweet spot in the optimization landscape (Li *et al.* 2018). The desired result is for the loss to approach as close to zero as possible at a decent pace to avoid excessive training time (red line).

The right figure is an example of a typical loss function over time while training a small network on CIFAR-10 dataset (Li *et al.* 2018). This loss function looks reasonable; however, it might have a slightly small learning rate based on its speed of decay, but that is just a speculation. The batch size might be a little too low since the cost is a little too noisy (Li *et al.* 2018).

The amount of noise in the loss is related to the batch size. When the batch size is 1, the noise will be relatively high. When the batch size is the full dataset, the noise will be minimal because every gradient update should be improving the loss function monotonically unless the learning rate is set too high (Li *et al.* 2018).

5.1.1.2 Train/Val accuracy

Training/validation accuracy is another essential quantity to track while training a classifier as it can provide valuable insight into the overfitting situation of the model.

The gap between the training and validation accuracy indicates the amount of overfitting (see figure below). The blue validation error curve shows minimal validation accuracy compared to the training accuracy, indicating strong overfitting and it is possible for the validation accuracy to even decreases after some point. If this situation happens in practice, incrementing regularisation (stronger L2 weight penalty, more dropout, etc.) or collect more data are possible solutions (Li *et al.* 2018). The green line shows validation accuracy tracks the training accuracy adequately. In this scenario, the model is good, but the model capacity is not high enough, a solution would be to make the model larger by increasing the number of parameters (Li *et al.* 2018).

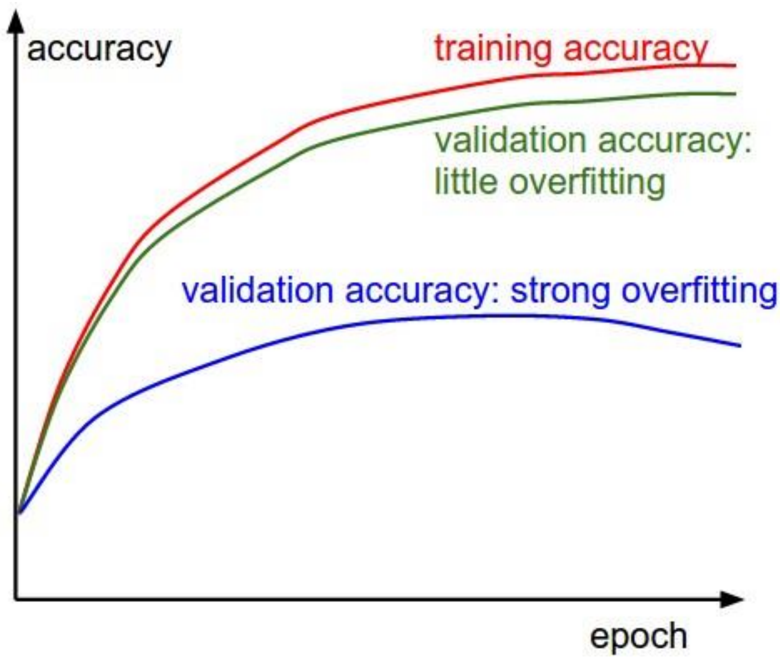

Figure 24: Possible interpretation of Training and Validation Accuracy (Li et al. 2018)

5.1.1.3 Ratio of weights: updates

Another quantity that is possible to track is the ratio of the update magnitudes to the value magnitudes. The updated ratio of weight should be evaluated and tracked for every set of parameters independently (Li *et al.* 2018). A rough heuristic is that this ratio should be somewhere around 1e-3. If it is lower than 1e-3 then the learning rate might be too low and vice versa (Li *et al.* 2018).

5.1.2 Analyse the Result

This section looks at metrics used to evaluate the performance of the algorithms in the experiment.

5.1.2.1 Prediction (Positives and Negatives)

Prediction for a binary classification problem can be separate into the following four; true positive, true negative, false positive and false negative (Google Developers 2019).

- **False positive** and **false negatives** are samples that were **incorrectly classified.**
- **True positive** and **true negatives** are samples that were **correctly classified.**

The figure below depicts the predictions of a familiar fable, "the boy who cried wolf", as a confusion matrix. This confusion matrix will be used to help explain a few of the up and coming metrics.

True Positives (TPs): 1 • Reality: A wolf threatened. • Shepherd said: "Wolf." • Outcome: Shepherd is a hero.	**False Positives (FPs): 1** • Reality: No wolf threatened. • Shepherd said: "Wolf." • Outcome: Villagers are angry at shepherd for waking them up.
False Negatives (FNs): 8 • Reality: A wolf threatened. • Shepherd said: "No wolf." • Outcome: The wolf ate all the sheep.	**True Negatives (TNs): 90** • Reality: No wolf threatened. • Shepherd said: "No wolf." • Outcome: Everyone is fine.

Figure 25: Confusion matrix to depicts the possible outcome for a binary classifier problem; where "Wolf" is a positive class and "No wolf" is a negative class (Google Developers 2019)

5.1.2.2 Accuracy

Informally, accuracy can be defined as the fraction of samples that the model correctly classified. Formally, accuracy has the following definition:

$$\text{Accuracy} = \frac{Number\ of\ correct\ prediction}{Total\ number\ of\ predictions}$$

In a binary classification problem, accuracy can be calculated in terms of positives and negatives as follows:

$$\text{Accuracy} = \frac{TP + TN}{TP + TN + FP + FN}$$

5.1.2.2.1 The problem

Accuracy alone does not provide meaningful evaluation of the result when working with a class-imbalanced dataset where there is significant disparity between the number of positive and negative labels. This problem is addressed using another set of measurement; precision and recall (Google Developers 2019).

5.1.2.3 *Precision and Recall*

5.1.2.3.1 Precision

Precision can be defined as the correct portion of the positive identification. Mathematically as follows:

$$\text{Precision} = \frac{TP}{TP + FP}$$

Using the confusion matrix (figure 26) as an example, the model has a prediction of 0.5 (see working out below). In other words, when the boy shouts "wolf", it is true 50% of the time, the other times he is lying.

$$\text{Precision} = \frac{TP}{TP + FP} = \frac{1}{1 + 1} = 0.5$$

5.1.2.3.2 Recall

Recall can be defined as correct portion of actual identification. Mathematically as follows:

$$\text{Recall} = \frac{TP}{TP + FN}$$

By using the previous confusion matrix (figure 26) as an example, the model has a prediction of 0.11 (see working out below). In other words, when the boy shouts "wolf", it is a wolf 11% of the time, the other times he could not tell the difference between a wolf and a black sheep.

$$\text{Recall} = \frac{TP}{TP + FN} = \frac{1}{1 + 8} = 0.11$$

5.1.2.3.3 Precision vs Recall

Examination of both precision and recall is necessary to fully evaluate the effectiveness of a model. Unfortunately, precision and recall are often in tension. This means, improving precision typically reduces recall and vice versa. There are various metrics that has been developed to rely on both precision and recall, an example of this is the F1 score metric (Google Developers 2019).

5.1.2.4 *F1 Score*

The F1 score can be interpreted as a weighted average of the precision and recall, where an F1 score reaches its best value at 1 and worst 0 (similar to precision and recall) (Sasaki 2007). The relative contribution of precision and recall to the F1 score are equal. Mathematically as follows:

$$\text{F1 Score} = \frac{2 \cdot Precision \cdot Recall}{Precision + Recall} = \frac{1}{1+8} = 0.11$$

5.1.2.4.1 <u>F1 Score vs Other Metrics</u>

Two popular metrics that are used in classification problem are F1 score and AUC. AUC refers to the Area Under the Curve of a Receiver Operating Characteristic curve (ROC-AUC). This metric is equal to the probability that a classifier will rank a random positive sample higher than a random negative sample (Google Developers 2019).

While the search for a good performance metric is still an open discussion, there's a tendency to use F1 score in real world problems where class imbalance tends to happen. This is because the sensitivity of Precision and Recall on an imbalanced dataset is reflected by the F1 score.

5.2 Experiment Procedure

5.2.1 Data and Training Setup

The data preprocessing for this project evolves depending on the model and version of the project. Application of preprocessing technique is analysed and discussed in the experiment analyses section with specific parameter setup available in the appendix for each experiment.

In all the experiment, each model is trained for 100 epochs for consistency and to ensure the validity of the experiment; chest x-ray images are organised into training (1341 normal, 3875 pneumonia), validation (8 normal, 8 pneumonia) and test (234 normal, 390 pneumonia) (view graph below).

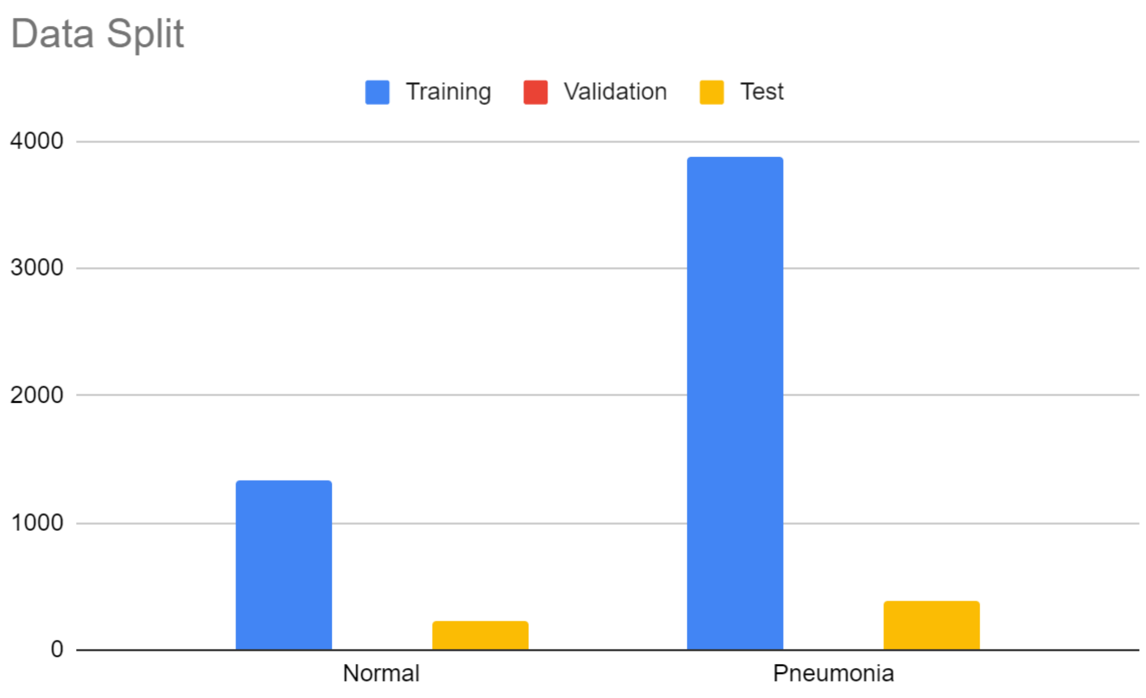

Figure 26: Kermany et al. (2018) CXR Dataset Split for this project

5.2.2 Model Setup

In this experiment, three models based on VGG16 network architecture are prototyped with each model architecture slightly modified, mostly in the classification layer.

ResNet 50V2, NasNet Mobile and InceptionResNetV2 model's prototype has their training method; feature learning part follows their respective architecture and the classification part modified based on VGG16 model 1 because of its simple structure and excellent results (further discussed in the experiment analyses section).

These models are further tested with different parameters to confirm the previous hypothesis and seek for best result.

5.2.2.1 VGG16 Model 0

VGG16 Model 0 is retrained from scratch without pre-trained weight. The model closely follows the VGG16 feature learning layers proposed by Simonyan and Zisserman (2014). The classification layers of the model consist of a flatten layer to convert the final three-dimensional hidden layer to a one-dimension array, and three FC layers with a dropout layer after the first two to prevent overfitting (see figure below). Each FC layer uses ReLU activation function apart from the two neurons output layer (last layer) which uses SoftMax activation function to predict pneumonia or normal result (see appendix A for full structure).

```
_________________________________________________________________
flatten (Flatten)            (None, 8192)              0
_________________________________________________________________
dense (Dense)                (None, 4096)              33558528
_________________________________________________________________
dropout (Dropout)            (None, 4096)              0
_________________________________________________________________
dense_1 (Dense)              (None, 4096)              16781312
_________________________________________________________________
dropout_1 (Dropout)          (None, 4096)              0
_________________________________________________________________
dense_2 (Dense)              (None, 2)                 8194
=================================================================
Total params: 65,062,722
Trainable params: 65,062,722
Non-trainable params: 0
```

Figure 27: VGG16 Model 0 Classification Part

5.2.2.2 VGG16 Model 1

VGG16 Model 1 uses a pre-trained model (Keras 2019) with weights pre-trained on ImageNet (Deng *et al.* 2009). Transfer learning is applied in this model to counteract the lack of data available (further discussed in experiment analyses section). The training extracts features from the feature learning part of the pre-trained model and retrains the classification part. Simplification of the classification part was made as an experiment. VGG16 Model 1 classification part includes a flatten layer and an output layer (see figure below) with the same specification for the same reasons as VGG16 Model 0. This is also our "shallowest" DNN in comparison to all other models prototyped in this project. For full detail of model structure view appendix x – the code.

```
_________________________________________________________________
flatten (Flatten)            (None, 8192)              0
_________________________________________________________________
dense (Dense)                (None, 2)                 16386
=================================================================
Total params: 14,731,074
Trainable params: 16,386
Non-trainable params: 14,714,688
```

Figure 28: VGG16 Model 1 Classification Part

5.2.2.3 VGG16 Model 2

VGG16 model 2 applies the same training method as model 1 with modification made to the classification part for experimental purposes further discussed in the experiment analyses section. The new classifier is made up by five layers in the following order: a flatten layer, a sixty-four neurons FC layer with ReLU activation, a dropout layer, a batch normalisation layer and an output layer. The extra FC layer is added to potentially increase the network training accuracy since "larger networks will always work better than smaller networks" (Li *et al.* 2018). The dropout layer is added after the FC layer to prevent potential overfitting (Srivastava *et al.* 2014), and batch normalisation as an extra layer of regularisation and potentially assist with carelessness in initialisation (Ioffe & Szegedy 2015).

```
_________________________________________________________________
flatten (Flatten)            (None, 8192)              0
_________________________________________________________________
dense (Dense)                (None, 64)                524352
_________________________________________________________________
dropout (Dropout)            (None, 64)                0
_________________________________________________________________
batch_normalization (BatchNo (None, 64)                256
_________________________________________________________________
dense_1 (Dense)              (None, 2)                 130
=================================================================
Total params: 15,239,426
Trainable params: 524,610
Non-trainable params: 14,714,816
```

Figure 29: VGG16 Model 2 Classification Part

5.2.3 Parameter Setup

The table below displays the parameter setup for each version of each model which are tested. The rationale for the selection of each parameter are discussed in the experiment analyses section if any parameter(s) is unexplained in certain version, they are kept in their general form as they are inferred to have a weak impact on the version. Setup information of each parameter such as data augmentation methods and class weight balancing is available their respective programs available for view in the appendices.

5.2.3.1 VGG16 Models Parameters

Table 1: VGG16 Models Experiment Parameters

Model	**VGG16 Model 0**			**VGG16 Model 1**					**VGG16 Model 2**		
Version	0.0.0.0.0	0.1.2.0.0	0.1.3.0.0	1.0.1.0.0	1.1.0.0.0	1.1.1.0.0	1.1.1.1.0	1.1.1.0.1	2.1.1.0.0	2.1.1.1.0	2.1.1.0.1
Pre-trained Weights	None	None	None	Image Net	Image Net	Image Net	Image Net	Image Net	Image Net	Image Net	Image Net
Data Augmentation	None	Applied	Applied	None	Applied	Applied	Applied	Applied	Applied	Applied	Applied
Optimizer	RMSprop (lr=0.001)	Adam(lr=0.001)	Adam(lr=0.0001)	RMSprop(lr=0.0001)	RMSprop (lr=0.001)	RMSprop (lr=0.0001)	RMSprop (lr=0.0001)	RMSprop (lr=0.0001)	RMSprop (lr=0.0001)	RMSprop (lr=0.0001)	RMSprop (lr=0.0001)
Class Weight Balancing	None	None	None	None	None	None	Applied	None	None	Applied	None
Batch Size	32	32	32	32	32	32	32	128	32	32	128

5.2.3.2 Other Models Parameters

Table 2: All Models Experiment Parameters

Model	**VGG16 Model 1**	**ResNet50V2**	**NasNetMobile**	**InceptionResNetV2**
Version	1.1.1.0.0	1.1.1.0.0	1.1.1.0.0	1.1.1.0.0
Pre-trained Weights	ImageNet	ImageNet	ImageNet	ImageNet
Data Augmentation	Applied	Applied	Applied	Applied
Optimizer	RMSprop (lr=0.0001)	RMSprop (lr=0.001)	RMSprop (lr=0.001)	RMSprop (lr=0.001)
Class Weight Balancing	None	None	None	None
Batch Size	32	32	32	32

5.2.4 Experiment Analyses

5.2.4.1 VGG16 Model 0

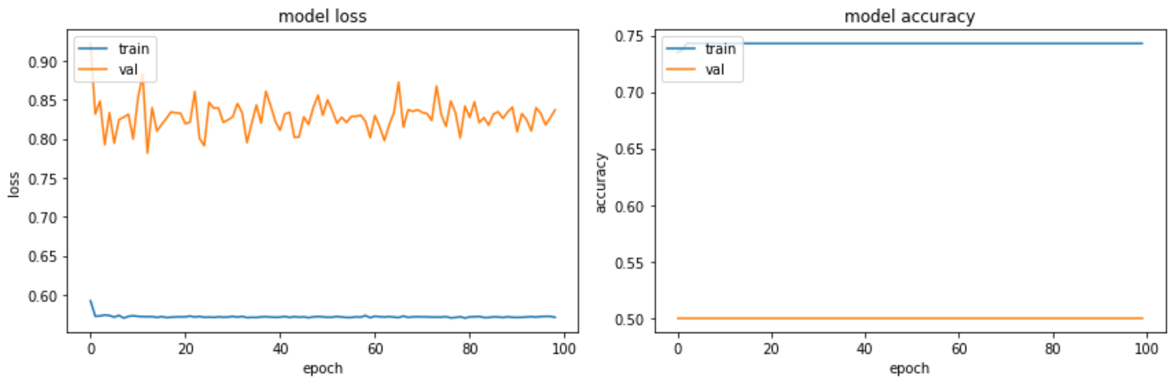

Figure 30: VGG16 Model 0 loss and accuracy

Observation of the learning process (see figure above) shows that the model's loss and accuracy halt at a relatively poor score in less than five epochs and there is a significant gap between the training and validation result.

The quick decay but early stop in training loss indicate that the learning rate may be too high, or there is a problem with the optimizer (Li *et al.* 2018). The large gap between training and validation is an indication of strong overfitting (Li *et al.* 2018).

A different optimizer was used in version 0.1.2.0.0 and version 0.1.3.0.0 and the learning rate was lower in version 0.1.3.0.0 as an attempt to resolve the first problem (see table 1). Data augmentation techniques were used in version 0.1.2.0.0 and version 0.1.3.0.0 simulate new data by increasing the diversity of data available to regulate overfitting without the need to obtain new data or modifying the model. However, these alterations were ineffective, as there were no changes to the result (see table 3).

We concluded that the first model is unable to learn and make any meaningful prediction due to the lack of data, especially for a model that is trained from scratch. A well-known solution in practice is to use a pre-trained network, known as transfer learning (Li *et al.* 2018). Transfer learning is used to improve performance on the current task with knowledge from previous task (Rosenstein *et al.* 2005).

5.2.4.2 VGG16 Model 1

The use of a pre-trained network with pre-trained weight produced significantly better training and validation result. Each modification in the parameter bears visible changes to the test result. Further analyses are discussed below.

5.2.4.2.1 VGG16 v1.0.1.0.0

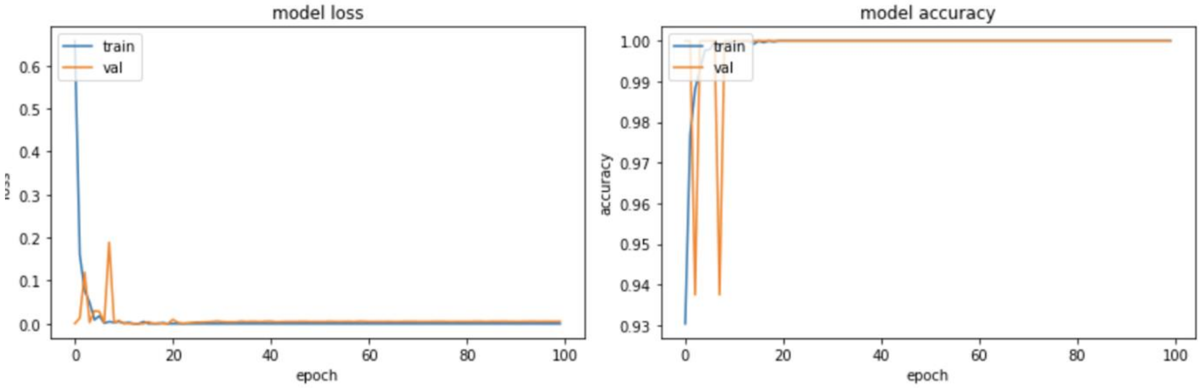

Figure 31: VGG16 model 1 version 1.0.1.0.0 model's loss and accuracy graph

The first version (v1.0.1.0.0) of VGG16 Model 1 displayed the highest results in training and validation in comparison to all other models tested in this project, both with *100% accuracy and 0% loss* (view table x and graph above). However, the model test results are quite low compared to its training and validation result, with a *test accuracy of 81.57%* and *F1-score of 87.12%*. The model may be overfitted as it does well with training and validation data but does not generalize well to predict the new test dataset.

The appropriate solution for the next step of the project is to augment the dataset to increase data variances as it requires the least intervention with the neural network comparing to other techniques previously discussed in the overfitting and underfitting section.

5.2.4.2.2 VGG16 v1.1.0.0.0

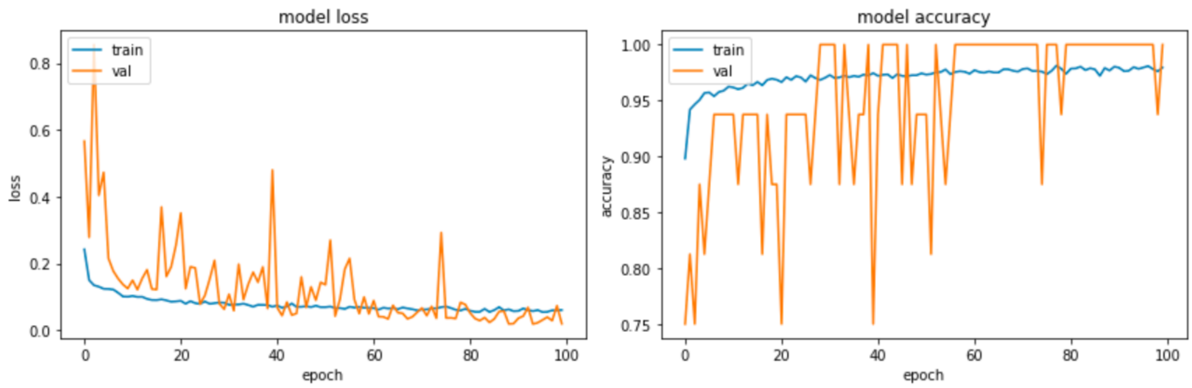

Figure 32: VGG16 model 1 version 1.1.0.0.0 model's loss and accuracy graph

The application of data augmentation in this version of the experiment brought forward some observable changes in the learning process (see figure above) alongside the final result. The final *training (loss: 5.68%, acc: 97.99%)* and *validation (loss: 1.81%, acc: 100%)* results of the model slightly worsen, and validation result is fiercely volatile throughout the process (view figure above). However, these results do not affect the final testing result negatively. The testing result increased significantly, *91.67% for accuracy and 93.45% for F1-Score* in this version (v1.1.0.0.0). A minimum increment of 10% for accuracy and 6% for F1 score is true for all other models which applies data augmentation (see table 4 – VGG16 Models Test Result).

Through the learning process, general validation results are reduced and the validation results are more volatile comparing to the previous version (VGG16 Model 1 version 1.0.1.0.0). The reduction in validation result is foreseeable since the training dataset was augmented thus improves the model's ability to generalise overall and reduces overfitting. However, to understand the high volatility, evaluation of the data split is necessary.

As previously shown, the amount of validation data is significantly less compared to the data for training and testing purposes (see figure 26 – data split). Therefore, when algorithm conducts prediction with the validation data, the result for each validation prediction has a more significant impact on the overall validation result especially when it is outputted as a percentage (view the figure above and table 3).

The solution to decreasing the volatility of the validation result is to increase the data available for validation. Unless more data are gathered, re-organisation of the data split is necessary to increase the validation data, contrarily decreases the training and testing data. In the current stage of the experiment, volatility does not seem to affect the outcome negatively; therefore, there is no reason to re-split the dataset.

For the next couple of experiment in VGG16 Model 1, the data augmentation parameters are kept constant because of its positive result. Other parameters such as the learning rate, weight class distribution and the batch size will be modified and analysed.

5.2.4.2.3 VGG16 v1.1.1.0.0 (Best Test Result)

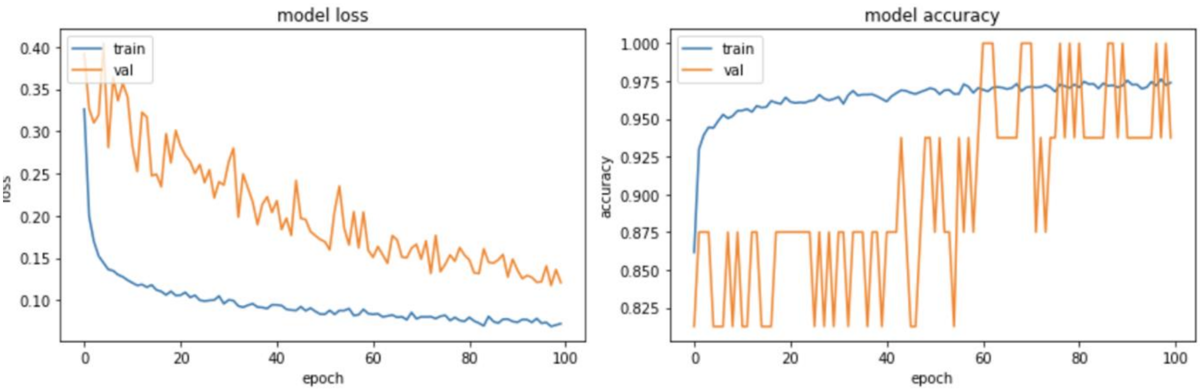

Figure 33: VGG16 model 1 version 1.1.1.0.0 model's loss and accuracy graph (model with best test result)

In the previous version of the experiment (v1.1.0.0.0), a learning rate of 0.001 was used comparing to 0.0001 from this version. The lower learning rate resulted in a slower exponential decay in training loss when the two model loss graphs are compared (see figure 32 and figure 33 model loss). Another noticeable feature in the graphs is the gap between training and validation has increased in both loss and accuracy graphs which may be a sign of overfitting.

By applying data augmentation and lower the learning rate, the overall test score in this version of model 1 is increased by approximately 1% (*Test Accuracy: 92.63%, F1 Score: 94.21%)*. Regularisation is attempted in the next model (VGG16 Model 2) to address overfitting in this model. Implementation details and analysis are discussed in VGG16 Model 2 section.

5.2.4.2.4 VGG16 v1.1.1.1.0

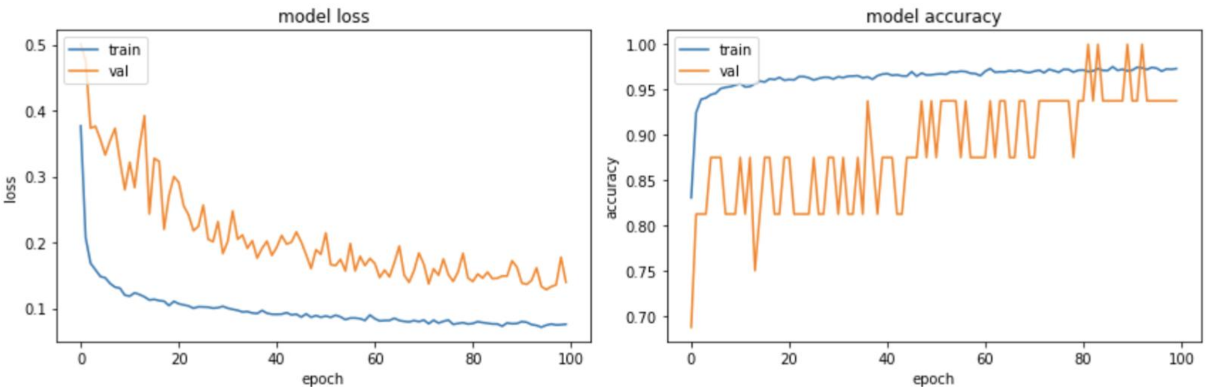

Figure 34: VGG16 model 1 version 1.1.1.1.0 model's loss and accuracy graph

In this version, class-weight balancing is applied to potentially improve training loss and accuracy (Tensorflow 2019). However, the examination of the learning process (see figure above) and the training/validation result (table 3) shows no significant changes in the learning process and the test result is more inferior in comparison to VGG16 model 1 version 1.1.1.0.0 (see table 4).

For most binary classification problem, it is preferable to have the class balance. However, each project is different and it is necessary to understand the desired outcome and the problem of each project.

204	30
16	374

Figure 35: Confusion Matrix - VGG16 model with no class balancing (v1.1.1.0.0)

203	31
18	372

Figure 36: Confusion Matrix - VGG16 model with class balancing (v1.1.1.1.0)

In this project, a dataset that is biased toward pneumonia has more chance of predicting false positive instead of false negatives (see figure 35 – VGG16 model with no class balancing) and vice versa (figure 36 – VGG16 model with class balancing). In simple term, a dataset that is biased toward pneumonia teaches the model to predict the image of a normal result as pneumonia positive rather than the image with pneumonia result as negative, in worst-case scenarios.

A pneumonia biased model is not the desired outcome since it is always better to improve the model to reach a final model with zero false prediction. However, if a model is unable to reach zero false prediction, then a model that predicts pneumonia when a patient does not have pneumonia (a pneumonia positive model) is preferred over a model that does not predict pneumonia when the patient has pneumonia. As pneumonia positive model brings experts attention to the problem rather than the dismissal of potential positive cases.

5.2.4.2.5 VGG16 v1.1.1.0.1

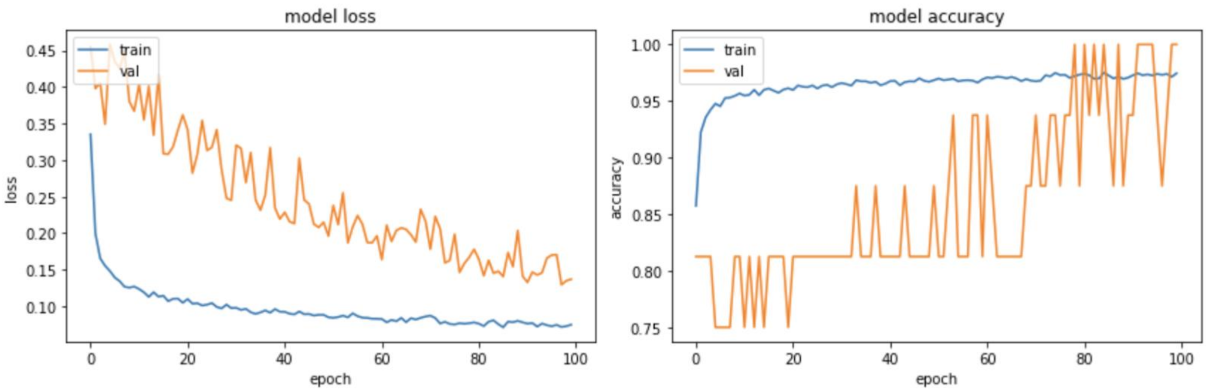

Figure 37: VGG16 model 1 version 1.1.1.0.1 model's loss and accuracy graph

This version of the program experiments with the batch size by increasing it from 32 to 128 to see the effect its on the project. Generally, a larger batch size decreases the model training time but also has the potential to decreases the model's ability to generalise effectively (Master & Luschi 2018).

By comparing training time and results (see table 3 and 4) of models with identical parameters apart from the batch size; VGG16 Model 1 version 1.1.1.0.0 (figure 38) and version 1.1.1.0.1 (figure 39). It is noted that the training time for both versions is relatively similar; however, the test result for 128 batch size version is slightly worse comparing to 32 batch size version (*F1-Score: 94.07% vs F1-Score: 94.21% respectively*). Thus, the result confirms that a larger batch size decreases the model's ability to generalise effectively but has no effect on the training time.

```
Epoch 1/100
162/163 [===========================>.] - ETA: 0s - loss: 0.3272 - acc: 0.8611Epoch 1/100
  1/163 [.............................] - ETA: 4:26 - loss: 0.3919 - acc: 0.8125
Epoch 00001: saving model to /content/data/model/weights.epoch_01.hdf5
163/163 [=============================] - 89s 546ms/step - loss: 0.3262 - acc: 0.8616 - val_loss: 0.3919 - val_acc: 0.8125
Epoch 2/100
162/163 [===========================>.] - ETA: 0s - loss: 0.1985 - acc: 0.9306Epoch 1/100
  1/163 [.............................] - ETA: 55s - loss: 0.3267 - acc: 0.8750
Epoch 00002: saving model to /content/data/model/weights.epoch_02.hdf5
163/163 [=============================] - 85s 523ms/step - loss: 0.1994 - acc: 0.9300 - val_loss: 0.3267 - val_acc: 0.8750
Epoch 3/100
162/163 [===========================>.] - ETA: 0s - loss: 0.1699 - acc: 0.9392Epoch 1/100
  1/163 [.............................] - ETA: 56s - loss: 0.3100 - acc: 0.8750
Epoch 00003: saving model to /content/data/model/weights.epoch_03.hdf5
163/163 [=============================] - 86s 529ms/step - loss: 0.1695 - acc: 0.9394 - val_loss: 0.3100 - val_acc: 0.8750
```

Figure 38: VGG16 model 1 version 1.1.1.0.0 Training Time Sample (32 Batch Size)

```
Epoch 1/100
162/163 [===========================>.] - ETA: 0s - loss: 0.3356 - acc: 0.8574Epoch 1/100
  1/163 [..............................] - ETA: 4:27 - loss: 0.4553 - acc: 0.8125
Epoch 00001: saving model to /content/data/model/weights.epoch_01.hdf5
163/163 [=============================] - 90s 554ms/step - loss: 0.3354 - acc: 0.8574 - val_loss: 0.4553 - val_acc: 0.8125
Epoch 2/100
162/163 [===========================>.] - ETA: 0s - loss: 0.1994 - acc: 0.9228Epoch 1/100
  1/163 [..............................] - ETA: 58s - loss: 0.3980 - acc: 0.8125
Epoch 00002: saving model to /content/data/model/weights.epoch_02.hdf5
163/163 [=============================] - 88s 541ms/step - loss: 0.1998 - acc: 0.9225 - val_loss: 0.3980 - val_acc: 0.8125
Epoch 3/100
162/163 [===========================>.] - ETA: 0s - loss: 0.1659 - acc: 0.9354Epoch 1/100
  1/163 [..............................] - ETA: 55s - loss: 0.4058 - acc: 0.8125
Epoch 00003: saving model to /content/data/model/weights.epoch_03.hdf5
163/163 [=============================] - 89s 549ms/step - loss: 0.1655 - acc: 0.9356 - val_loss: 0.4058 - val_acc: 0.8125
```

Figure 39: Training Time Sample - VGG16 model 1 version 1.1.1.0.1 (128 Batch Size)

5.2.4.3 VGG16 Model 2

All version for VGG16 Model 2 inherits the optimizer, learning rate and data augmentation technique of VGG16 Model 1 version 1.1.1.0.0 because of the success with those parameters. Experiment with the class-weight distribution and batch size will be carried out along with a modification to the classification part of the neural network.

5.2.4.3.1 <u>VGG16 v2.1.1.0.0</u>

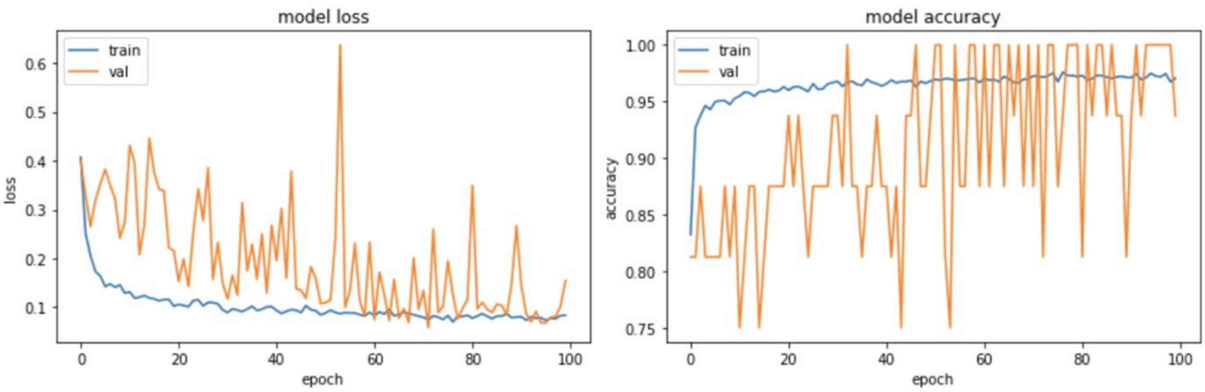

Figure 40: VGG16 model 2 version 2.1.1.0.0 model's loss and accuracy graph

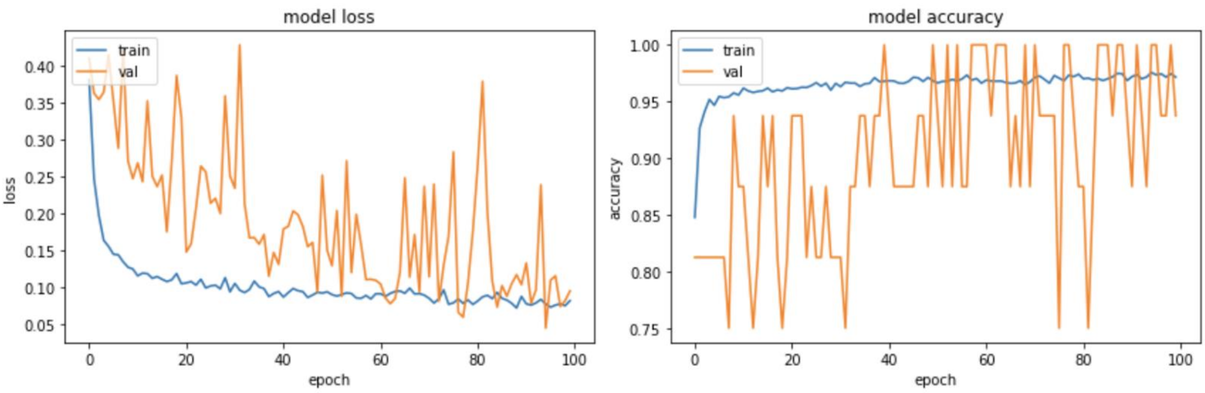

Figure 41: VGG16 model 2 version 2.1.1.1.0 model's loss and accuracy graph

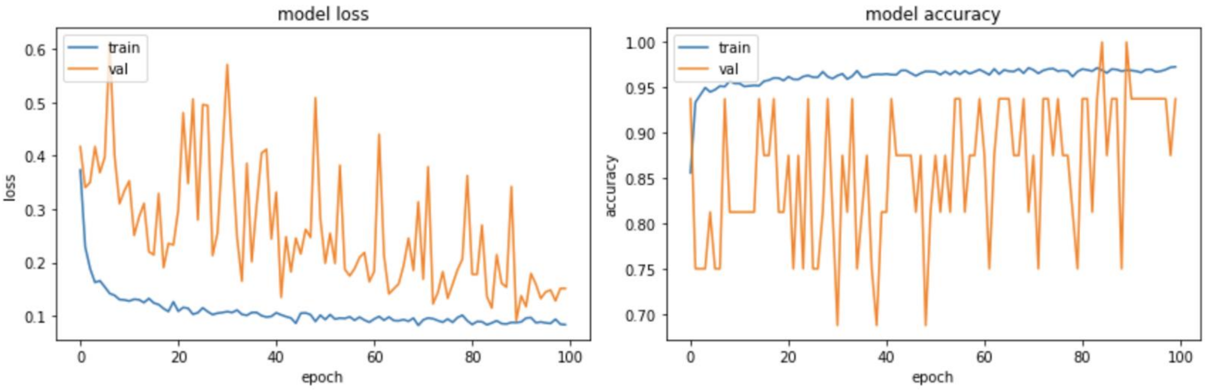

Figure 42: VGG16 model 2 version 2.1.1.0.1 model's loss and accuracy graph

From the three prototypes of VGG16 model 2, version 2.1.1.1.0 (class-weight balancing applied) produces the best validation result but also has the worst testing result. Version 2.1.1.0.0 has an average validation result but has the best testing result (Test Accuracy: 92.15%, Test F1-Score: 93.82%).

VGG16 Model 2 will be evaluated as a whole instead individually since the change in result for the three prototyped in model 2 (2.1.1.0.0, 2.1.1.1.0, 2.1.1.0.1) reflected their counterpart in version 1 (1.1.1.0.0, 1.1.1.1.0, 1.1.1.0.1).

As previously predicted in the model setup section, applying regularisation to the neural network reduced overfitting, which can be observed in the better trend in validation loss and accuracy (see figures above). However, training loss and accuracy slightly decrease when compared to their respective prototype in model 1 (see table 3). The test result, specifically the F1-Score also decreased by the same amount with the *best F1-Score of 93.82% in model 2 version 2.1.1.0.0*. Another noticeable feature from the graphs is the validation volatility which has increased (view figures above).

The reduction in training loss and accuracy could potentially come from the change in model architecture with no modification to the learning rate or the model's architecture in general. The increase in validation volatility may be due to the lower amount of data available for validation (previously discussed in the analysis of model 1 version 1.1.1.0.0). However, these statements are only speculation; more testing is required.

5.2.4.4 VGG16 Result Overview

5.2.4.4.1 Training and Validation Result

Table 3: VGG16 Models Training and Validation Best Result based on Validation Loss

Model	**VGG16 Model 0**			**VGG16 Model 1**					**VGG16 Model 2**		
Version	0.0.0.0.0	0.1.2.0.0	0.1.3.0.0	1.0.1.0.0	1.1.0.0.0	1.1.1.0.0	1.1.1.1.0	1.1.1.0.1	2.1.1.0.0	2.1.1.1.0	2.1.1.0.1
Training Loss	414.39%	414.39%	414.39%	0.00%	5.68%	6.88%	7.41%	7.17%	7.45%	7.69%	8.71%
Training Accuracy	74.29%	74.29%	74.29%	100.00%	97.99%	97.62%	97.36%	97.39%	97.22%	97.57%	96.89%
Validation Loss	805.90%	805.90%	805.90%	0.00%	1.81%	11.75%	12.83%	12.94%	5.83%	4.41%	9.11%
Validation Accuracy	50.00%	50.00%	50.00%	100.00%	100.00%	93.75%	93.75%	93.75%	100.00%	100.00%	100.00%

5.2.4.4.2 Testing Result

Table 4: VGG16 Models Testing Result

Model	**VGG16 Model 0**			**VGG16 Model 1**					**VGG16 Model 2**		
Version	0.0.0.0.0	0.1.2.0.0	0.1.3.0.0	1.0.1.0.0	1.1.0.0.0	1.1.1.0.0	1.1.1.1.0	1.1.1.0.1	2.1.1.0.0	2.1.1.1.0	2.1.1.0.1
Accuracy	-	-	-	81.57%	91.67%	92.63%	92.15%	92.47%	92.15%	91.35%	91.83%
Precision	-	-	-	77.34%	91.83%	92.57%	92.31%	92.56%	92.31%	90.98%	91.65%
Recall	-	-	-	99.74%	95.13%	95.90%	95.38%	95.64%	95.38%	95.64%	95.64%
F1 Score	-	-	-	87.12%	93.45%	94.21%	93.82%	94.07%	93.82%	93.25%	93.60%

5.3 Other Models

The experiment for ResNet50V2, NasNetMobile, Inception-ResNetV2 models are carried out using VGG16 model 1 version 1.1.1.0.0 as a base (previously mentioned in the model setup section). Thus, their feature learning part follows the original structure proposed by their respected authors (view about model section). The classification part and parameters are set in accordance with VGG16 model 1 version 1.1.1.0.0.

5.3.1 Experiment Analyses

5.3.1.1 ResNet50V2 model 1 version 1.1.1.0.0

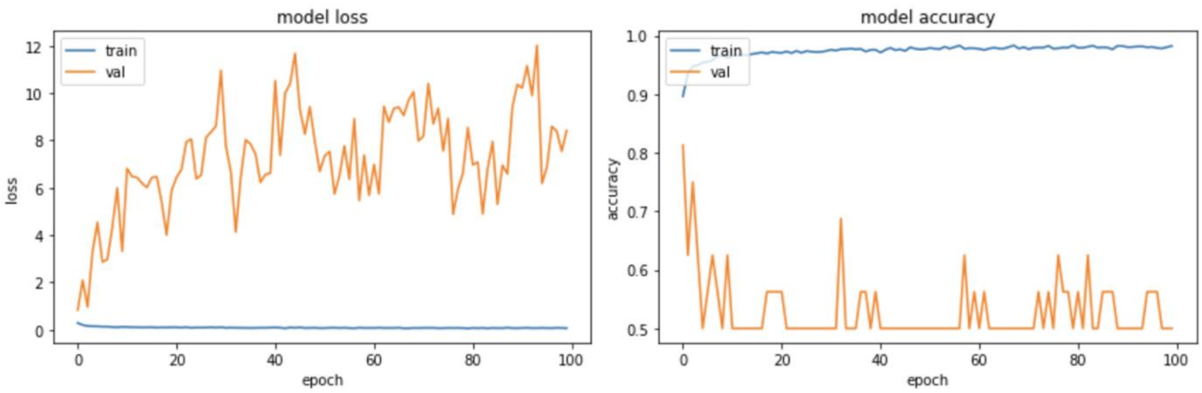

Figure 43: ResNet50V2 model 1 version 1.1.1.0.0 model's loss and accuracy graph

The learning process (view graph above) shows that the validation result initially begins at a relatively good spot but separates itself from the training result after each iteration. The trend in the validation result movement assumes the possibility of overfitting in this learning model, which is a high possibility since this model does not implement regularisation.

The best training loss and accuracy for this model are 0.060 and 0.982 respectively (see appendix J – ResNet50V2), which is better than the best training loss and accuracy in VGG16 model 1 version 1.1.1.0. (0.068 and 0.976 respectively). There is a high chance that this model will produce the best result if overfitting is resolved.

5.3.1.2 NasNetMobile model 1 version 1.1.1.0.0

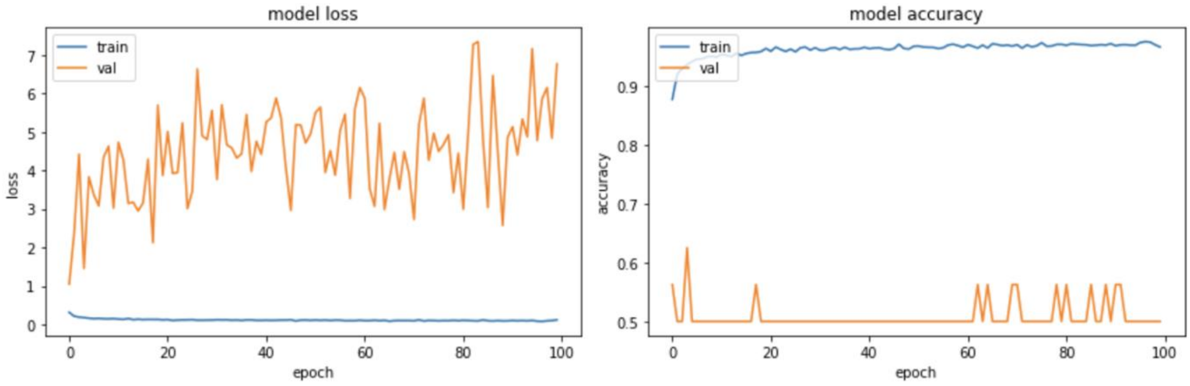

Figure 44: NasNetMobile model 1 version 1.1.1.0.0 model's loss and accuracy graph

NasNetMobile v1.1.1.0.0 has a training loss of ~0.1 and accuracy of ~0.970 after 100 epochs. By comparing NasNetMobile graph (figure 44) and ResNetV2 graph (figure 43), the validation loss in these models are certainly trending positively. However, NasNetMobile validation loss range is smaller than ResNetV2 (left graph, figure 44 and figure 43 respectively) and validation accuracy flats out more quickly.

13	221
1	389

Figure 45: Confusion Matrix - NasNetMobile model

Another important remark is from the test result in table 6, NasNetMobile's has a recall value of 99.74% which is unusually high when it has the lowest accuracy and F1 score comparing to the other three models, but this is nothing out of the ordinary. By reviewing the model's confusion matrix (figure 45), we can see that the model is predicting positive (pneumonia) most of the time. If the model only makes positive predictions, the result for Recall will be 100% and Accuracy will be 62.5% since the test data set contains 234 normal images and 390 pneumonia images.

Apart from the likelihood that the model is overfitted due to lack of regularisation, there is a possibility that the model has not learned the relevant patterns from the training dataset which could be related to the architecture generated by NasNetMobile network as the structure is quite a mystery. However, further work is required to be carried out before any more assumption is made.

5.3.1.3 *Inception-ResNetV2 model 1 version 1.1.1.0.0*

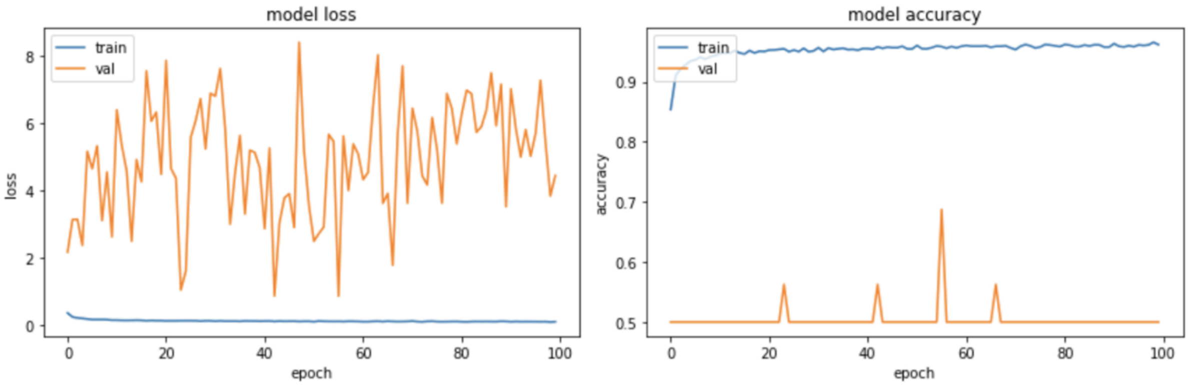

Figure 46: Inception-ResNetV2 model 1 version 1.1.1.0.0 model's loss and accuracy graph

The training, validation and testing results for Inception-ResNetV2 model based on validation loss is better than NasNetMobile model. However, there are a few other results we need to review to understand the overall picture. First, Inception-ResNetV2 model's training loss and accuracy after 100 epochs are approximately 0.96 and 0.10 respectively, which is the lowest comparing to all other v1.1.1.0.0 models. Second, the validation accuracy is very steady. Similar to NasNetMobile, this model may be overfitted and have not to truly learned from the training dataset due to the lack of data.

5.3.1.4 *Result Overview*

5.3.1.4.1 Training and Validation Result

Table 5: All Models Training and Validation Best Result based on Validation Loss

Model	**VGG16 Model 1**	**ResNet50V2**	**NasNetMobile**	**InceptionResNetV2**
Version	1.1.1.0.0	1.1.1.0.0	1.1.1.0.0	1.1.1.0.0
Training Loss	6.88%	28.18%	31.39%	11.69%
Training Accuracy	97.62%	89.67%	87.69%	95.88%
Validation Loss	11.75%	83.04%	105.02%	86.60%
Validation Accuracy	93.75%	81.25%	56.25%	68.75%

5.3.1.4.2 Testing Result

Table 6: All Models Testing Result

Model	**VGG16 Model 1**	**ResNet50V2**	**NasNetMobile**	**InceptionResNetV2**
Version	1.1.1.0.0	1.1.1.0.0	1.1.1.0.0	1.1.1.0.0
Accuracy	92.63%	80.93%	64.42%	77.56%
Precision	92.57%	79.01%	63.77%	74.51%
Recall	95.90%	94.62%	99.74%	97.44%
F1 Score	94.21%	86.11%	77.80%	84.44%

5.4 Final Selection

As previously predicted in the model selection section of the report, VGG16 network produced the best test result with a *Test Accuracy of 92.63% and an F1 Score of 94.21%* by *VGG16 model 1 version 1.1.1.0.0.* However, this result may be biased since more time was spent on VGG16 configuration and testing in comparison to the other networks. The initial assumption was that a "simple model" where the distribution of parameter values has less entropy or a model with fewer parameters are less likely to overfit (Tensorflow 2019). The thought following the assumption is that less overfitting is equal to a better chance of a higher result. However, as more careful research was conducted through the review stage, a statement made by Li *et al.* (2018) suggested that "larger networks will always work better than smaller networks, but their higher model capacity must be appropriately addressed with stronger regularization". This statement brought forward an incompleteness to the project since regularisation was not addressed in other networks apart from VGG16. Another remark that supports the use of larger networks is the usage of transfer learning. When transfer learning is applied in this project, the feature learning layers are extracted (not trained) and the classification layers are fine-tuned. Therefore, the number of trainable parameters is only the ones from the classification layers.

Another decision that was problematic after the experiment was conducted to avoid using the ROC/AUC measurement. In the early stage, the decision to use F1-score metric over AUC (Area under the ROC Curve) was made due to concern regarding the application of an imbalance dataset. This project prefers to utilise the imbalance dataset to predict a false positive instead of a false negative. Therefore, AUC is not a useful metric for this scenario (Google Developer 2019). However, difficulties arise as comparison between the project and reviewed works is necessary since these literature mainly use AUC as their metric.

6 Conclusion

The goal of this project is to prototype a deep learning algorithm to detect visual signals of pneumonia infection, in simpler term, to classify pneumonia in chest x-rays. A collection of deep neural networks which includes VGG16 (Simonyan & Zisserman 2014), ResNet50V2 (He *et al.* 2016b), NasNetMobile (Zoph & Le 2016) and InceptionResNetV2 (Szegedy *et al.* 2017) were modified, trained and tested on the Mendeley chest x-ray dataset (Kermany *et al.* 2018) for the task. The best result of 92.63% for Test Accuracy and 94.21% for F1-Score is achieved by the VGG16 (model 1 version 1.1.1.0.0) network using transfer learning with pre-trained weight from ImageNet (Deng *et al.* 2009) and simple classification layers consist of a flatten layer and an output layer with SoftMax activation. The project has shown that training methods and pre-processing action can improve the result significantly. The F1-score achieved by the best model in this project (VGG16 model 1 version 1.1.1.0.0) is significantly higher than previously reviewed literature such as Rajpurkar *et al.* (2017); 0.942 vs 0.435 respectively. However, it is unviable to make this comparison since these projects are conducted on different datasets. In the end, the goal of the project is achieved, withal, there are rooms for further improvement.

7 Future Iteration

Future work for this project may be separated into sections according to the report structure (data, model and experiment). There are potential improvements or explorable elements in each stage of the project.

When looking at data, the use of a small dataset created problems throughout the experimental phase of the project. A significant amount of time was required to address these problems as previously shown. Creating a model for a small dataset has its benefits; however, for a real-world problem, the performance of a model created from small dataset on more varied inputs is questionable. Prototyping a model with a successful result on a big dataset may be more valuable and will also allow for easier comparison with existing works.

There are a few debatable misjudgements which were made in the project “model section” with the leading one being the modification of an overwhelming number of parameters. The focus on parameters modification is justifiable as they were the potential solution to the problem, which were analysed. Nevertheless, this focus on parameter and one primary model (VGG16) took away the opportunity to understand other models’ performance fully. Another approach would be to set generic parameters and focus on fine-tuning a few neural networks where more time would be spent on understanding the NNs and adjusting its classification layers with regularisation and other techniques. In the end, this approach has not been carried out and may or may not produce better result in comparison to the original approach.

When looking at the experiment section, the biggest misstep would be the decision to avoid using the ROC/AUC metric. This decision made it significantly difficult to compare this work to reviewed works. In future iterations, more research on the use case of evaluation metrics is required and frequent reflection of the project overall should be performed. In the time of uncertainty, it may be best to take both choices when it is manageable to execute.

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9 Appendices

The following appendices contains markdowned files of the all the programs in this project. Follow the link below to access Google Colab executable source files.

https://github.com/jhqthai/xray-pneumonia-detection

9.1 Appendix A: VGG16 Model 0

VGG16 Model 0

Hardware: Google Collab GPU

Software: Tensorflow, Keras

Dataset: 5,863 X-Ray images (JPEG) and 2 categories (Pneumonia/Normal). https://data.mendeley.com/datasets/rscbjbr9sj/2

This model objective is to classify pneumonia in chest x-ray. This model initial build from the guidance from community and resources such as Tensorflow Community, Google Colab Community, Medium and other resources. Specific project that are closely related to this can be found below.

Reference

- Google Collab - rock, paper, scissors notebook: https://colab.research.google.com/github/lmoroney/dlaicourse/blob/master/Course%202%20-%20Part%208%20-%20Lesson%202%20-%20Notebook%20(RockPaperScissors).ipynb#scrollTo=LWTisYLQM1aM
- Easy to understand notebook: https://www.kaggle.com/joythabo33/99-accurate-cnn-that-detects-pneumonia/notebook
- Unit8 pneumonia git: https://github.com/unit8co/amld-workshop-pneumonia/tree/master/3_pneumonia

----

```
!pip install tensorflow-gpu
```

```
Collecting tensorflow-gpu
[?25l  Downloading https://files.pythonhosted.org/packages/25/44/47f0722ae
a081697143fbcf5d2aa60d1aee4aaacb5869aee2b568974777b/tensorflow_gpu-2.0.0-c
p36-cp36m-manylinux2010_x86_64.whl (380.8MB)
[K     |████████████████████████████████| 380.8MB 84kB/s
[?25hRequirement already satisfied: keras-preprocessing>=1.0.5 in /usr/loc
al/lib/python3.6/dist-packages (from tensorflow-gpu) (1.1.0)
Requirement already satisfied: keras-applications>=1.0.8 in /usr/local/lib
```

```
/python3.6/dist-packages (from tensorflow-gpu) (1.0.8)
Requirement already satisfied: gast==0.2.2 in /usr/local/lib/python3.6/dis
t-packages (from tensorflow-gpu) (0.2.2)
Requirement already satisfied: opt-einsum>=2.3.2 in /usr/local/lib/python3
.6/dist-packages (from tensorflow-gpu) (3.1.0)
Requirement already satisfied: wrapt>=1.11.1 in /usr/local/lib/python3.6/d
ist-packages (from tensorflow-gpu) (1.11.2)
Requirement already satisfied: protobuf>=3.6.1 in /usr/local/lib/python3.6
/dist-packages (from tensorflow-gpu) (3.7.1)
Collecting tensorboard<2.1.0,>=2.0.0 (from tensorflow-gpu)
[?25l  Downloading https://files.pythonhosted.org/packages/9b/a6/e8ffa4e2d
db216449d34cfcb825ebb38206bee5c4553d69e7bc8bc2c5d64/tensorboard-2.0.0-py3-
none-any.whl (3.8MB)
[K     |████████████████████████████████| 3.8MB 27.0MB/s
[?25hRequirement already satisfied: termcolor>=1.1.0 in /usr/local/lib/pyt
hon3.6/dist-packages (from tensorflow-gpu) (1.1.0)
Requirement already satisfied: wheel>=0.26 in /usr/local/lib/python3.6/dis
t-packages (from tensorflow-gpu) (0.33.6)
Requirement already satisfied: google-pasta>=0.1.6 in /usr/local/lib/pytho
n3.6/dist-packages (from tensorflow-gpu) (0.1.7)
Requirement already satisfied: absl-py>=0.7.0 in /usr/local/lib/python3.6/
dist-packages (from tensorflow-gpu) (0.8.0)
Collecting tensorflow-estimator<2.1.0,>=2.0.0 (from tensorflow-gpu)
[?25l  Downloading https://files.pythonhosted.org/packages/95/00/5e6cdf861
90a70d7382d320b2b04e4ff0f8191a37d90a422a2f8ff0705bb/tensorflow_estimator-2
.0.0-py2.py3-none-any.whl (449kB)
[K     |████████████████████████████████| 450kB 48.7MB/s
[?25hRequirement already satisfied: grpcio>=1.8.6 in /usr/local/lib/python
3.6/dist-packages (from tensorflow-gpu) (1.15.0)
Requirement already satisfied: astor>=0.6.0 in /usr/local/lib/python3.6/di
st-packages (from tensorflow-gpu) (0.8.0)
Requirement already satisfied: six>=1.10.0 in /usr/local/lib/python3.6/dis
t-packages (from tensorflow-gpu) (1.12.0)
Requirement already satisfied: numpy<2.0,>=1.16.0 in /usr/local/lib/python
3.6/dist-packages (from tensorflow-gpu) (1.16.5)
Requirement already satisfied: h5py in /usr/local/lib/python3.6/dist-packa
ges (from keras-applications>=1.0.8->tensorflow-gpu) (2.8.0)
Requirement already satisfied: setuptools in /usr/local/lib/python3.6/dist
-packages (from protobuf>=3.6.1->tensorflow-gpu) (41.2.0)
Requirement already satisfied: werkzeug>=0.11.15 in /usr/local/lib/python3
.6/dist-packages (from tensorboard<2.1.0,>=2.0.0->tensorflow-gpu) (0.16.0)
Requirement already satisfied: markdown>=2.6.8 in /usr/local/lib/python3.6
/dist-packages (from tensorboard<2.1.0,>=2.0.0->tensorflow-gpu) (3.1.1)
[31mERROR: tensorflow 1.15.0rc3 has requirement tensorboard<1.16.0,>=1.15.
0, but you'll have tensorboard 2.0.0 which is incompatible.[0m
[31mERROR: tensorflow 1.15.0rc3 has requirement tensorflow-estimator==1.15
.1, but you'll have tensorflow-estimator 2.0.0 which is incompatible.[0m
Installing collected packages: tensorboard, tensorflow-estimator, tensorfl
ow-gpu
  Found existing installation: tensorboard 1.15.0
    Uninstalling tensorboard-1.15.0:
      Successfully uninstalled tensorboard-1.15.0
  Found existing installation: tensorflow-estimator 1.15.1
    Uninstalling tensorflow-estimator-1.15.1:
```

```
    Successfully uninstalled tensorflow-estimator-1.15.1
Successfully installed tensorboard-2.0.0 tensorflow-estimator-2.0.0 tensor
flow-gpu-2.0.0
```

```
import tensorflow as tf
print(tf.__version__)
```

The default version of TensorFlow in Colab will soon switch to TensorFlow 2.x. We recommend you upgrade now or ensure your notebook will continue to use TensorFlow 1.x via the %tensorflow_version 1.x magic: more info.

```
1.15.0
```

```
!ls /content/
```

```
sample_data
```

```
!du -s /content/data/chest_xray
```

```
1219956 /content/data/chest_xray
```

```
!du /content/data/chest_xray
```

```
du: cannot access '/content/data/chest_xray': No such file or directory
```

```
!pwd
```

```
/content
```

Make directory

To save the dataset

```
!mkdir /content/data/
```

Download the dataset

Downloading from unit8 instead of from directly mendeley database since this dataset is splitted and available to downloaded here.

```
!wget --no-check-certificate \
    https://s3.eu-central-1.amazonaws.com/public.unit8.co/data/chest_xray.
tar.gz \
    -O /content/data/chest_xray.tar.gz
```

```
--2019-11-14 06:11:29--  https://s3.eu-central-1.amazonaws.com/public.unit
8.co/data/chest_xray.tar.gz
Resolving s3.eu-central-1.amazonaws.com (s3.eu-central-1.amazonaws.com)...
52.219.72.143
Connecting to s3.eu-central-1.amazonaws.com (s3.eu-central-1.amazonaws.com
)|52.219.72.143|:443... connected.
HTTP request sent, awaiting response... 200 OK
```

```
Length: 1225393795 (1.1G) [application/x-gzip]
Saving to: '/content/data/chest_xray.tar.gz'

/content/data/chest 100%[===================>]   1.14G  98.2MB/s    in 12s

2019-11-14 06:11:41 (95.9 MB/s) - '/content/data/chest_xray.tar.gz' saved
[1225393795/1225393795]
```

Extract the downloaded zip file

```
import os
import tarfile

tar = tarfile.open("data/chest_xray.tar.gz")
tar.extractall(path='./data/')
os.remove('data/chest_xray.tar.gz')
```

Data preprocessing and manipulation

```
import keras_preprocessing
from keras_preprocessing.image import ImageDataGenerator # Data preprocess
ing and augmentation

TRAINING_DIR = "/content/data/chest_xray/train"
VALIDATION_DIR = "/content/data/chest_xray/val"
TEST_DIR = "/content/data/chest_xray/test"

# TODO: Data augmentation - Fiddle with images for training
training_datagen = ImageDataGenerator(
    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,
    fill_mode='nearest'
)

validation_datagen = ImageDataGenerator()

test_datagen = ImageDataGenerator()

# Create training data batch
# TODO: Try grayscaling the image to see what will happen
train_generator = training_datagen.flow_from_directory(
    TRAINING_DIR,
    target_size=(150,150), # Resize the image to 150px x 150px; Why? idk..
. Check Unit8 work..
    class_mode='categorical'
)

validation_generator = validation_datagen.flow_from_directory(
```

```
    VALIDATION_DIR,
    target_size=(150,150),
    class_mode='categorical'
)

test_generator = test_datagen.flow_from_directory(
    TEST_DIR,
    target_size=(150,150),
    class_mode='categorical'
)
```

```
Found 5216 images belonging to 2 classes.
Found 16 images belonging to 2 classes.
Found 624 images belonging to 2 classes.
```

```
train_generator.image_shape
```

```
(150, 150, 3)
```

Define the Model

VGG16 model for Keras

This is the Keras model of the 16-layer network used by the VGG team in the ILSVRC-2014 competition.

It has been obtained by directly converting the Caffe model provived by the authors.

Details about the network architecture can be found in the following arXiv paper:

Very Deep Convolutional Networks for Large-Scale Image Recognition K. Simonyan, A. Zisserman arXiv:1409.1556

In the paper, the VGG-16 model is denoted as configuration D. It achieves 7.5% top-5 error on ILSVRC-2012-val, 7.4% top-5 error on ILSVRC-2012-test.

```
#VGG16 Model
model = tf.keras.models.Sequential([
    # First convolution layer
    tf.keras.layers.ZeroPadding2D((1,1),input_shape=train_generator.image_
shape),
    tf.keras.layers.Conv2D(64, (3, 3), activation='relu'),
    tf.keras.layers.ZeroPadding2D((1,1)),
    tf.keras.layers.Conv2D(64, (3, 3), activation='relu'),
    tf.keras.layers.MaxPooling2D((2,2), strides=(2,2)),

    # Second convolution layer
    tf.keras.layers.ZeroPadding2D((1,1)),
    tf.keras.layers.Conv2D(128, (3, 3), activation='relu'),
    tf.keras.layers.ZeroPadding2D((1,1)),
    tf.keras.layers.Conv2D(128, (3, 3), activation='relu'),
    tf.keras.layers.MaxPooling2D((2,2), strides=(2,2)),

    # Third convolution layer
    tf.keras.layers.ZeroPadding2D((1,1)),
```

```
    tf.keras.layers.Conv2D(256, (3, 3), activation='relu'),
    tf.keras.layers.ZeroPadding2D((1,1)),
    tf.keras.layers.Conv2D(256, (3, 3), activation='relu'),
    tf.keras.layers.ZeroPadding2D((1,1)),
    tf.keras.layers.Conv2D(256, (3, 3), activation='relu'),
    tf.keras.layers.MaxPooling2D((2,2), strides=(2,2)),

    # Fourth convolution layer
    tf.keras.layers.ZeroPadding2D((1,1)),
    tf.keras.layers.Conv2D(512, (3, 3), activation='relu'),
    tf.keras.layers.ZeroPadding2D((1,1)),
    tf.keras.layers.Conv2D(512, (3, 3), activation='relu'),
    tf.keras.layers.ZeroPadding2D((1,1)),
    tf.keras.layers.Conv2D(512, (3, 3), activation='relu'),
    tf.keras.layers.MaxPooling2D((2,2), strides=(2,2)),

    # Fifth convolution layer
    tf.keras.layers.ZeroPadding2D((1,1)),
    tf.keras.layers.Conv2D(512, (3, 3), activation='relu'),
    tf.keras.layers.ZeroPadding2D((1,1)),
    tf.keras.layers.Conv2D(512, (3, 3), activation='relu'),
    tf.keras.layers.ZeroPadding2D((1,1)),
    tf.keras.layers.Conv2D(512, (3, 3), activation='relu'),
    tf.keras.layers.MaxPooling2D((2,2), strides=(2,2)),

    # Flatten the results and feed into a DNN
    tf.keras.layers.Flatten(),
    tf.keras.layers.Dense(4096, activation='relu'),
    tf.keras.layers.Dropout(0.5),
    tf.keras.layers.Dense(4096, activation='relu'),
    tf.keras.layers.Dropout(0.5),
    tf.keras.layers.Dense(2, activation='softmax')
])

model.summary()
```

```
WARNING:tensorflow:From /usr/local/lib/python3.6/dist-packages/tensorflow_
core/python/ops/resource_variable_ops.py:1630: calling BaseResourceVariabl
e.__init__ (from tensorflow.python.ops.resource_variable_ops) with constra
int is deprecated and will be removed in a future version.
Instructions for updating:
If using Keras pass *_constraint arguments to layers.
Model: "sequential"
_________________________________________________________________
Layer (type)                 Output Shape              Param #
=================================================================
zero_padding2d (ZeroPadding2 (None, 152, 152, 3)       0
_________________________________________________________________
conv2d (Conv2D)              (None, 150, 150, 64)      1792
_________________________________________________________________
zero_padding2d_1 (ZeroPaddin (None, 152, 152, 64)      0
_________________________________________________________________
conv2d_1 (Conv2D)            (None, 150, 150, 64)      36928
_________________________________________________________________
```

```
max_pooling2d (MaxPooling2D) (None, 75, 75, 64)        0
zero_padding2d_2 (ZeroPaddin (None, 77, 77, 64)        0
conv2d_2 (Conv2D)            (None, 75, 75, 128)       73856
zero_padding2d_3 (ZeroPaddin (None, 77, 77, 128)       0
conv2d_3 (Conv2D)            (None, 75, 75, 128)       147584
max_pooling2d_1 (MaxPooling2 (None, 37, 37, 128)       0
zero_padding2d_4 (ZeroPaddin (None, 39, 39, 128)       0
conv2d_4 (Conv2D)            (None, 37, 37, 256)       295168
zero_padding2d_5 (ZeroPaddin (None, 39, 39, 256)       0
conv2d_5 (Conv2D)            (None, 37, 37, 256)       590080
zero_padding2d_6 (ZeroPaddin (None, 39, 39, 256)       0
conv2d_6 (Conv2D)            (None, 37, 37, 256)       590080
max_pooling2d_2 (MaxPooling2 (None, 18, 18, 256)       0
zero_padding2d_7 (ZeroPaddin (None, 20, 20, 256)       0
conv2d_7 (Conv2D)            (None, 18, 18, 512)       1180160
zero_padding2d_8 (ZeroPaddin (None, 20, 20, 512)       0
conv2d_8 (Conv2D)            (None, 18, 18, 512)       2359808
zero_padding2d_9 (ZeroPaddin (None, 20, 20, 512)       0
conv2d_9 (Conv2D)            (None, 18, 18, 512)       2359808
max_pooling2d_3 (MaxPooling2 (None, 9, 9, 512)         0
zero_padding2d_10 (ZeroPaddi (None, 11, 11, 512)       0
conv2d_10 (Conv2D)           (None, 9, 9, 512)         2359808
zero_padding2d_11 (ZeroPaddi (None, 11, 11, 512)       0
conv2d_11 (Conv2D)           (None, 9, 9, 512)         2359808
zero_padding2d_12 (ZeroPaddi (None, 11, 11, 512)       0
conv2d_12 (Conv2D)           (None, 9, 9, 512)         2359808
max_pooling2d_4 (MaxPooling2 (None, 4, 4, 512)         0
```

```
flatten (Flatten)            (None, 8192)            0
_________________________________________________________________
dense (Dense)                (None, 4096)            33558528
_________________________________________________________________
dropout (Dropout)            (None, 4096)            0
_________________________________________________________________
dense_1 (Dense)              (None, 4096)            16781312
_________________________________________________________________
dropout_1 (Dropout)          (None, 4096)            0
_________________________________________________________________
dense_2 (Dense)              (None, 2)               8194
=================================================================
Total params: 65,062,722
Trainable params: 65,062,722
Non-trainable params: 0
_________________________________________________________________
```

Callbacks function

```
early_stopping_monitor = tf.keras.callbacks.EarlyStopping(patience = 3, mo
nitor = "val_accuracy", mode="max", verbose = 1)
```

Compile the model

Here we use the “cross-entropy” loss function, which works well for learning probability distributions for classification.

See e.g.: https://ml-cheatsheet.readthedocs.io/en/latest/loss_functions.html#cross-entropy

```
# optimizer = tf.keras.optimizers.Adam(learning_rate= 0.0001)
optimizer = 'rmsprop'
model.compile(loss='categorical_crossentropy',
              optimizer=optimizer,
              metrics=['accuracy'])
```

Since the training set is un-balanced. Calculate the classweight to be used for weight balancing to solve accuracy and loss being stucked.

```
import sklearn
import numpy as np

classweight = sklearn.utils.class_weight.compute_class_weight('balanced',
np.unique(train_generator.labels), train_generator.labels)
print(classweight)
```

```
[1.9448173  0.67303226]
```

Train the model

```
# Training process
history = model.fit_generator(
    generator=train_generator,
    # steps_per_epoch=500,
```

```
    epochs=100,
    # callbacks=[early_stopping_monitor],
    shuffle=True,
    validation_data=validation_generator,
    # validation_steps=10,
    class_weight=classweight,
    verbose = 1
    )

# model.save("pneumonia_detection_v1")

### Plot training
import matplotlib.pyplot as plt
def plot_learning_curves(history):
    plt.figure(figsize=(12,4))

    plt.subplot(1,2,1)
    plt.plot(history.history['loss'])
    plt.plot(history.history['val_loss'])
    plt.title('model loss')
    plt.ylabel('loss')
    plt.xlabel('epoch')
    plt.legend(['train', 'val'], loc='upper left')

    plt.subplot(1,2,2)
    plt.plot(history.history['acc'])
    plt.plot(history.history['val_acc'])
    plt.title('model accuracy')
    plt.ylabel('accuracy')
    plt.xlabel('epoch')
    plt.legend(['train', 'val'], loc='upper left')

    plt.tight_layout()

plot_learning_curves(history)

## Load best weight
idx = np.argmin(history.history['val_loss'])
model.load_weights("/content/data/model/weights.epoch_{:02d}.hdf5".format(
idx + 1))

print("Loading the best model")
print("epoch: {}, val_loss: {}, val_acc: {}".format(idx + 1, history.histo
ry['val_loss'][idx], history.history['val_acc'][idx]))

## Evaluate the model
test_loss, test_acc = model.evaluate_generator(generator=test_generator, v
erbose=1)

## Analytics
from sklearn.metrics import accuracy_score, confusion_matrix

test_generator.reset()
test_preds = model.predict_generator(test_generator, verbose=1)
```

```
test_preds = np.argmax(test_preds,axis=1)

acc = accuracy_score(test_generator.classes, test_preds)*100
cm = confusion_matrix(test_generator.classes, test_preds)
tn, fp, fn, tp = cm.ravel()

print('CONFUSION MATRIX ------------------')
print(cm)
# plot_confusion_matrix(cm, target_names=['NORMAL', 'PNEUMONIA'], normaliz
e=False)


print('\nTEST METRICS ----------------------')
precision = tp/(tp+fp)*100
recall = tp/(tp+fn)*100
print('Accuracy: {}%'.format(acc))
print('Precision: {}%'.format(precision))
print('Recall: {}%'.format(recall))
print('F1-score: {}'.format(2*precision*recall/(precision+recall)))

print('\nTRAIN METRIC ----------------------')
print('Train acc: {}%'.format(np.round((history.history['acc'][-1])*100, 1
4)))
```

```
Epoch 1/100
162/163 [============================>.] - ETA: 0s - loss: 1197.9604 - acc
: 0.7350Epoch 1/100
163/163 [==============================] - 116s 712ms/step - loss: 1190.61
47 - acc: 0.7349 - val_loss: 0.8432 - val_acc: 0.5000
Epoch 2/100
162/163 [============================>.] - ETA: 0s - loss: 0.5927 - acc: 0
.7365Epoch 1/100
163/163 [==============================] - 109s 671ms/step - loss: 0.5921
- acc: 0.7370 - val_loss: 0.9222 - val_acc: 0.5000
Epoch 3/100
162/163 [============================>.] - ETA: 0s - loss: 0.5728 - acc: 0
.7425Epoch 1/100
163/163 [==============================] - 110s 675ms/step - loss: 0.5723
- acc: 0.7429 - val_loss: 0.8318 - val_acc: 0.5000
Epoch 4/100
162/163 [============================>.] - ETA: 0s - loss: 0.5734 - acc: 0
.7423Epoch 1/100
163/163 [==============================] - 110s 673ms/step - loss: 0.5727
- acc: 0.7429 - val_loss: 0.8482 - val_acc: 0.5000
Epoch 5/100
162/163 [============================>.] - ETA: 0s - loss: 0.5742 - acc: 0
.7427Epoch 1/100
163/163 [==============================] - 109s 669ms/step - loss: 0.5740
- acc: 0.7429 - val_loss: 0.7923 - val_acc: 0.5000
Epoch 6/100
162/163 [============================>.] - ETA: 0s - loss: 0.5732 - acc: 0
.7429Epoch 1/100
163/163 [==============================] - 109s 668ms/step - loss: 0.5732
- acc: 0.7429 - val_loss: 0.8334 - val_acc: 0.5000
```

```
Epoch 7/100
162/163 [============================>.] - ETA: 0s - loss: 0.5707 - acc: 0
.7434Epoch 1/100
163/163 [==============================] - 108s 666ms/step - loss: 0.5713
- acc: 0.7429 - val_loss: 0.7943 - val_acc: 0.5000
Epoch 8/100
162/163 [============================>.] - ETA: 0s - loss: 0.5736 - acc: 0
.7427Epoch 1/100
163/163 [==============================] - 110s 674ms/step - loss: 0.5734
- acc: 0.7429 - val_loss: 0.8244 - val_acc: 0.5000
Epoch 9/100
162/163 [============================>.] - ETA: 0s - loss: 0.5703 - acc: 0
.7427Epoch 1/100
163/163 [==============================] - 108s 661ms/step - loss: 0.5700
- acc: 0.7429 - val_loss: 0.8276 - val_acc: 0.5000
Epoch 10/100
162/163 [============================>.] - ETA: 0s - loss: 0.5720 - acc: 0
.7431Epoch 1/100
163/163 [==============================] - 108s 664ms/step - loss: 0.5722
- acc: 0.7429 - val_loss: 0.8314 - val_acc: 0.5000
Epoch 11/100
162/163 [============================>.] - ETA: 0s - loss: 0.5721 - acc: 0
.7438Epoch 1/100
163/163 [==============================] - 109s 667ms/step - loss: 0.5730
- acc: 0.7429 - val_loss: 0.7996 - val_acc: 0.5000
Epoch 12/100
162/163 [============================>.] - ETA: 0s - loss: 0.5719 - acc: 0
.7431Epoch 1/100
163/163 [==============================] - 109s 668ms/step - loss: 0.5721
- acc: 0.7429 - val_loss: 0.8517 - val_acc: 0.5000
Epoch 13/100
162/163 [============================>.] - ETA: 0s - loss: 0.5720 - acc: 0
.7429Epoch 1/100
163/163 [==============================] - 109s 667ms/step - loss: 0.5719
- acc: 0.7429 - val_loss: 0.8824 - val_acc: 0.5000
Epoch 14/100
162/163 [============================>.] - ETA: 0s - loss: 0.5715 - acc: 0
.7431Epoch 1/100
163/163 [==============================] - 109s 666ms/step - loss: 0.5717
- acc: 0.7429 - val_loss: 0.7816 - val_acc: 0.5000
Epoch 15/100
162/163 [============================>.] - ETA: 0s - loss: 0.5725 - acc: 0
.7423Epoch 1/100
163/163 [==============================] - 108s 663ms/step - loss: 0.5719
- acc: 0.7429 - val_loss: 0.8398 - val_acc: 0.5000
Epoch 16/100
162/163 [============================>.] - ETA: 0s - loss: 0.5701 - acc: 0
.7436Epoch 1/100
163/163 [==============================] - 109s 668ms/step - loss: 0.5708
- acc: 0.7429 - val_loss: 0.8098 - val_acc: 0.5000
Epoch 17/100
162/163 [============================>.] - ETA: 0s - loss: 0.5709 - acc: 0
.7438Epoch 1/100
163/163 [==============================] - 109s 666ms/step - loss: 0.5719
```

```
- acc: 0.7429 - val_loss: 0.8182 - val_acc: 0.5000
Epoch 18/100
162/163 [============================>.] - ETA: 0s - loss: 0.5705 - acc: 0
.7431Epoch 1/100
163/163 [==============================] - 109s 669ms/step - loss: 0.5706
- acc: 0.7429 - val_loss: 0.8260 - val_acc: 0.5000
Epoch 19/100
162/163 [============================>.] - ETA: 0s - loss: 0.5719 - acc: 0
.7421Epoch 1/100
163/163 [==============================] - 108s 665ms/step - loss: 0.5710
- acc: 0.7429 - val_loss: 0.8343 - val_acc: 0.5000
Epoch 20/100
162/163 [============================>.] - ETA: 0s - loss: 0.5720 - acc: 0
.7425Epoch 1/100
163/163 [==============================] - 109s 671ms/step - loss: 0.5715
- acc: 0.7429 - val_loss: 0.8331 - val_acc: 0.5000
Epoch 21/100
162/163 [============================>.] - ETA: 0s - loss: 0.5718 - acc: 0
.7427Epoch 1/100
163/163 [==============================] - 109s 671ms/step - loss: 0.5716
- acc: 0.7429 - val_loss: 0.8327 - val_acc: 0.5000
Epoch 22/100
162/163 [============================>.] - ETA: 0s - loss: 0.5716 - acc: 0
.7429Epoch 1/100
163/163 [==============================] - 109s 669ms/step - loss: 0.5716
- acc: 0.7429 - val_loss: 0.8192 - val_acc: 0.5000
Epoch 23/100
162/163 [============================>.] - ETA: 0s - loss: 0.5717 - acc: 0
.7436Epoch 1/100
163/163 [==============================] - 109s 670ms/step - loss: 0.5725
- acc: 0.7429 - val_loss: 0.8213 - val_acc: 0.5000
Epoch 24/100
162/163 [============================>.] - ETA: 0s - loss: 0.5724 - acc: 0
.7421Epoch 1/100
163/163 [==============================] - 109s 670ms/step - loss: 0.5714
- acc: 0.7429 - val_loss: 0.8605 - val_acc: 0.5000
Epoch 25/100
162/163 [============================>.] - ETA: 0s - loss: 0.5708 - acc: 0
.7442Epoch 1/100
163/163 [==============================] - 109s 671ms/step - loss: 0.5721
- acc: 0.7429 - val_loss: 0.8005 - val_acc: 0.5000
Epoch 26/100
162/163 [============================>.] - ETA: 0s - loss: 0.5699 - acc: 0
.7440Epoch 1/100
163/163 [==============================] - 109s 667ms/step - loss: 0.5710
- acc: 0.7429 - val_loss: 0.7911 - val_acc: 0.5000
Epoch 27/100
162/163 [============================>.] - ETA: 0s - loss: 0.5718 - acc: 0
.7425Epoch 1/100
163/163 [==============================] - 109s 666ms/step - loss: 0.5713
- acc: 0.7429 - val_loss: 0.8466 - val_acc: 0.5000
Epoch 28/100
162/163 [============================>.] - ETA: 0s - loss: 0.5712 - acc: 0
.7427Epoch 1/100
```

```
163/163 [==============================] - 109s 667ms/step - loss: 0.5709
- acc: 0.7429 - val_loss: 0.8391 - val_acc: 0.5000
Epoch 29/100
162/163 [============================>.] - ETA: 0s - loss: 0.5718 - acc: 0
.7427Epoch 1/100
163/163 [==============================] - 109s 667ms/step - loss: 0.5716
- acc: 0.7429 - val_loss: 0.8394 - val_acc: 0.5000
Epoch 30/100
162/163 [============================>.] - ETA: 0s - loss: 0.5714 - acc: 0
.7427Epoch 1/100
163/163 [==============================] - 109s 669ms/step - loss: 0.5712
- acc: 0.7429 - val_loss: 0.8210 - val_acc: 0.5000
Epoch 31/100
162/163 [============================>.] - ETA: 0s - loss: 0.5718 - acc: 0
.7425Epoch 1/100
163/163 [==============================] - 108s 665ms/step - loss: 0.5713
- acc: 0.7429 - val_loss: 0.8241 - val_acc: 0.5000
Epoch 32/100
162/163 [============================>.] - ETA: 0s - loss: 0.5726 - acc: 0
.7425Epoch 1/100
163/163 [==============================] - 108s 664ms/step - loss: 0.5721
- acc: 0.7429 - val_loss: 0.8282 - val_acc: 0.5000
Epoch 33/100
162/163 [============================>.] - ETA: 0s - loss: 0.5714 - acc: 0
.7427Epoch 1/100
163/163 [==============================] - 109s 667ms/step - loss: 0.5712
- acc: 0.7429 - val_loss: 0.8451 - val_acc: 0.5000
Epoch 34/100
162/163 [============================>.] - ETA: 0s - loss: 0.5715 - acc: 0
.7434Epoch 1/100
163/163 [==============================] - 108s 663ms/step - loss: 0.5721
- acc: 0.7429 - val_loss: 0.8330 - val_acc: 0.5000
Epoch 35/100
162/163 [============================>.] - ETA: 0s - loss: 0.5707 - acc: 0
.7429Epoch 1/100
163/163 [==============================] - 108s 666ms/step - loss: 0.5706
- acc: 0.7429 - val_loss: 0.7951 - val_acc: 0.5000
Epoch 36/100
162/163 [============================>.] - ETA: 0s - loss: 0.5704 - acc: 0
.7434Epoch 1/100
163/163 [==============================] - 109s 666ms/step - loss: 0.5709
- acc: 0.7429 - val_loss: 0.8195 - val_acc: 0.5000
Epoch 37/100
162/163 [============================>.] - ETA: 0s - loss: 0.5717 - acc: 0
.7421Epoch 1/100
163/163 [==============================] - 108s 665ms/step - loss: 0.5708
- acc: 0.7429 - val_loss: 0.8433 - val_acc: 0.5000
Epoch 38/100
162/163 [============================>.] - ETA: 0s - loss: 0.5709 - acc: 0
.7434Epoch 1/100
163/163 [==============================] - 108s 660ms/step - loss: 0.5715
- acc: 0.7429 - val_loss: 0.8200 - val_acc: 0.5000
Epoch 39/100
162/163 [============================>.] - ETA: 0s - loss: 0.5716 - acc: 0
```

```
.7431Epoch 1/100
163/163 [==============================] - 108s 660ms/step - loss: 0.5718
- acc: 0.7429 - val_loss: 0.8608 - val_acc: 0.5000
Epoch 40/100
162/163 [============================>.] - ETA: 0s - loss: 0.5722 - acc: 0
.7421Epoch 1/100
163/163 [==============================] - 108s 662ms/step - loss: 0.5713
- acc: 0.7429 - val_loss: 0.8423 - val_acc: 0.5000
Epoch 41/100
162/163 [============================>.] - ETA: 0s - loss: 0.5710 - acc: 0
.7429Epoch 1/100
163/163 [==============================] - 108s 664ms/step - loss: 0.5709
- acc: 0.7429 - val_loss: 0.8221 - val_acc: 0.5000
Epoch 42/100
162/163 [============================>.] - ETA: 0s - loss: 0.5713 - acc: 0
.7429Epoch 1/100
163/163 [==============================] - 108s 664ms/step - loss: 0.5712
- acc: 0.7429 - val_loss: 0.8108 - val_acc: 0.5000
Epoch 43/100
162/163 [============================>.] - ETA: 0s - loss: 0.5717 - acc: 0
.7432Epoch 1/100
163/163 [==============================] - 107s 659ms/step - loss: 0.5721
- acc: 0.7429 - val_loss: 0.8318 - val_acc: 0.5000
Epoch 44/100
162/163 [============================>.] - ETA: 0s - loss: 0.5704 - acc: 0
.7432Epoch 1/100
163/163 [==============================] - 108s 665ms/step - loss: 0.5708
- acc: 0.7429 - val_loss: 0.8337 - val_acc: 0.5000
Epoch 45/100
162/163 [============================>.] - ETA: 0s - loss: 0.5714 - acc: 0
.7432Epoch 1/100
163/163 [==============================] - 108s 662ms/step - loss: 0.5718
- acc: 0.7429 - val_loss: 0.8018 - val_acc: 0.5000
Epoch 46/100
162/163 [============================>.] - ETA: 0s - loss: 0.5711 - acc: 0
.7431Epoch 1/100
163/163 [==============================] - 108s 665ms/step - loss: 0.5712
- acc: 0.7429 - val_loss: 0.8023 - val_acc: 0.5000
Epoch 47/100
162/163 [============================>.] - ETA: 0s - loss: 0.5719 - acc: 0
.7425Epoch 1/100
163/163 [==============================] - 108s 664ms/step - loss: 0.5715
- acc: 0.7429 - val_loss: 0.8279 - val_acc: 0.5000
Epoch 48/100
162/163 [============================>.] - ETA: 0s - loss: 0.5697 - acc: 0
.7436Epoch 1/100
163/163 [==============================] - 108s 665ms/step - loss: 0.5704
- acc: 0.7429 - val_loss: 0.8184 - val_acc: 0.5000
Epoch 49/100
162/163 [============================>.] - ETA: 0s - loss: 0.5718 - acc: 0
.7427Epoch 1/100
163/163 [==============================] - 109s 668ms/step - loss: 0.5715
- acc: 0.7429 - val_loss: 0.8399 - val_acc: 0.5000
Epoch 50/100
```

```
162/163 [============================>.] - ETA: 0s - loss: 0.5718 - acc: 0
.7431Epoch 1/100
163/163 [==============================] - 109s 671ms/step - loss: 0.5719
- acc: 0.7429 - val_loss: 0.8559 - val_acc: 0.5000
Epoch 51/100
162/163 [============================>.] - ETA: 0s - loss: 0.5712 - acc: 0
.7432Epoch 1/100
163/163 [==============================] - 109s 670ms/step - loss: 0.5716
- acc: 0.7429 - val_loss: 0.8300 - val_acc: 0.5000
Epoch 52/100
162/163 [============================>.] - ETA: 0s - loss: 0.5712 - acc: 0
.7427Epoch 1/100
163/163 [==============================] - 110s 672ms/step - loss: 0.5710
- acc: 0.7429 - val_loss: 0.8499 - val_acc: 0.5000
Epoch 53/100
162/163 [============================>.] - ETA: 0s - loss: 0.5717 - acc: 0
.7425Epoch 1/100
163/163 [==============================] - 109s 671ms/step - loss: 0.5711
- acc: 0.7429 - val_loss: 0.8358 - val_acc: 0.5000
Epoch 54/100
162/163 [============================>.] - ETA: 0s - loss: 0.5720 - acc: 0
.7429Epoch 1/100
163/163 [==============================] - 109s 668ms/step - loss: 0.5720
- acc: 0.7429 - val_loss: 0.8200 - val_acc: 0.5000
Epoch 55/100
162/163 [============================>.] - ETA: 0s - loss: 0.5717 - acc: 0
.7425Epoch 1/100
163/163 [==============================] - 109s 669ms/step - loss: 0.5713
- acc: 0.7429 - val_loss: 0.8275 - val_acc: 0.5000
Epoch 56/100
162/163 [============================>.] - ETA: 0s - loss: 0.5705 - acc: 0
.7431Epoch 1/100
163/163 [==============================] - 109s 666ms/step - loss: 0.5708
- acc: 0.7429 - val_loss: 0.8209 - val_acc: 0.5000
Epoch 57/100
162/163 [============================>.] - ETA: 0s - loss: 0.5709 - acc: 0
.7429Epoch 1/100
163/163 [==============================] - 108s 665ms/step - loss: 0.5708
- acc: 0.7429 - val_loss: 0.8285 - val_acc: 0.5000
Epoch 58/100
162/163 [============================>.] - ETA: 0s - loss: 0.5714 - acc: 0
.7431Epoch 1/100
163/163 [==============================] - 108s 665ms/step - loss: 0.5716
- acc: 0.7429 - val_loss: 0.8287 - val_acc: 0.5000
Epoch 59/100
162/163 [============================>.] - ETA: 0s - loss: 0.5715 - acc: 0
.7427Epoch 1/100
163/163 [==============================] - 108s 665ms/step - loss: 0.5712
- acc: 0.7429 - val_loss: 0.8302 - val_acc: 0.5000
Epoch 60/100
162/163 [============================>.] - ETA: 0s - loss: 0.5728 - acc: 0
.7432Epoch 1/100
163/163 [==============================] - 109s 667ms/step - loss: 0.5732
- acc: 0.7429 - val_loss: 0.8224 - val_acc: 0.5000
```

```
Epoch 61/100
162/163 [============================>.] - ETA: 0s - loss: 0.5699 - acc: 0
.7434Epoch 1/100
163/163 [==============================] - 109s 667ms/step - loss: 0.5705
- acc: 0.7429 - val_loss: 0.8015 - val_acc: 0.5000
Epoch 62/100
162/163 [============================>.] - ETA: 0s - loss: 0.5718 - acc: 0
.7434Epoch 1/100
163/163 [==============================] - 109s 666ms/step - loss: 0.5724
- acc: 0.7429 - val_loss: 0.8297 - val_acc: 0.5000
Epoch 63/100
162/163 [============================>.] - ETA: 0s - loss: 0.5718 - acc: 0
.7429Epoch 1/100
163/163 [==============================] - 109s 668ms/step - loss: 0.5717
- acc: 0.7429 - val_loss: 0.8152 - val_acc: 0.5000
Epoch 64/100
162/163 [============================>.] - ETA: 0s - loss: 0.5708 - acc: 0
.7434Epoch 1/100
163/163 [==============================] - 109s 666ms/step - loss: 0.5713
- acc: 0.7429 - val_loss: 0.7977 - val_acc: 0.5000
Epoch 65/100
162/163 [============================>.] - ETA: 0s - loss: 0.5718 - acc: 0
.7431Epoch 1/100
163/163 [==============================] - 109s 669ms/step - loss: 0.5719
- acc: 0.7429 - val_loss: 0.8175 - val_acc: 0.5000
Epoch 66/100
162/163 [============================>.] - ETA: 0s - loss: 0.5715 - acc: 0
.7427Epoch 1/100
163/163 [==============================] - 109s 667ms/step - loss: 0.5712
- acc: 0.7429 - val_loss: 0.8333 - val_acc: 0.5000
Epoch 67/100
162/163 [============================>.] - ETA: 0s - loss: 0.5702 - acc: 0
.7432Epoch 1/100
163/163 [==============================] - 109s 669ms/step - loss: 0.5707
- acc: 0.7429 - val_loss: 0.8725 - val_acc: 0.5000
Epoch 68/100
162/163 [============================>.] - ETA: 0s - loss: 0.5720 - acc: 0
.7434Epoch 1/100
163/163 [==============================] - 109s 666ms/step - loss: 0.5726
- acc: 0.7429 - val_loss: 0.8148 - val_acc: 0.5000
Epoch 69/100
162/163 [============================>.] - ETA: 0s - loss: 0.5709 - acc: 0
.7429Epoch 1/100
163/163 [==============================] - 109s 668ms/step - loss: 0.5709
- acc: 0.7429 - val_loss: 0.8371 - val_acc: 0.5000
Epoch 70/100
162/163 [============================>.] - ETA: 0s - loss: 0.5714 - acc: 0
.7431Epoch 1/100
163/163 [==============================] - 109s 670ms/step - loss: 0.5716
- acc: 0.7429 - val_loss: 0.8350 - val_acc: 0.5000
Epoch 71/100
162/163 [============================>.] - ETA: 0s - loss: 0.5716 - acc: 0
.7431Epoch 1/100
163/163 [==============================] - 108s 663ms/step - loss: 0.5717
```

```
- acc: 0.7429 - val_loss: 0.8372 - val_acc: 0.5000
Epoch 72/100
162/163 [============================>.] - ETA: 0s - loss: 0.5722 - acc: 0
.7423Epoch 1/100
163/163 [==============================] - 109s 667ms/step - loss: 0.5715
- acc: 0.7429 - val_loss: 0.8337 - val_acc: 0.5000
Epoch 73/100
162/163 [============================>.] - ETA: 0s - loss: 0.5715 - acc: 0
.7429Epoch 1/100
163/163 [==============================] - 109s 666ms/step - loss: 0.5715
- acc: 0.7429 - val_loss: 0.8322 - val_acc: 0.5000
Epoch 74/100
162/163 [============================>.] - ETA: 0s - loss: 0.5713 - acc: 0
.7429Epoch 1/100
163/163 [==============================] - 109s 671ms/step - loss: 0.5712
- acc: 0.7429 - val_loss: 0.8234 - val_acc: 0.5000
Epoch 75/100
162/163 [============================>.] - ETA: 0s - loss: 0.5717 - acc: 0
.7425Epoch 1/100
163/163 [==============================] - 110s 675ms/step - loss: 0.5712
- acc: 0.7429 - val_loss: 0.8675 - val_acc: 0.5000
Epoch 76/100
162/163 [============================>.] - ETA: 0s - loss: 0.5720 - acc: 0
.7421Epoch 1/100
163/163 [==============================] - 110s 672ms/step - loss: 0.5712
- acc: 0.7429 - val_loss: 0.8309 - val_acc: 0.5000
Epoch 77/100
162/163 [============================>.] - ETA: 0s - loss: 0.5722 - acc: 0
.7425Epoch 1/100
163/163 [==============================] - 110s 672ms/step - loss: 0.5718
- acc: 0.7429 - val_loss: 0.8158 - val_acc: 0.5000
Epoch 78/100
162/163 [============================>.] - ETA: 0s - loss: 0.5692 - acc: 0
.7438Epoch 1/100
163/163 [==============================] - 110s 675ms/step - loss: 0.5703
- acc: 0.7429 - val_loss: 0.8483 - val_acc: 0.5000
Epoch 79/100
162/163 [============================>.] - ETA: 0s - loss: 0.5712 - acc: 0
.7425Epoch 1/100
163/163 [==============================] - 109s 671ms/step - loss: 0.5708
- acc: 0.7429 - val_loss: 0.8331 - val_acc: 0.5000
Epoch 80/100
162/163 [============================>.] - ETA: 0s - loss: 0.5709 - acc: 0
.7436Epoch 1/100
163/163 [==============================] - 110s 674ms/step - loss: 0.5717
- acc: 0.7429 - val_loss: 0.8011 - val_acc: 0.5000
Epoch 81/100
162/163 [============================>.] - ETA: 0s - loss: 0.5698 - acc: 0
.7431Epoch 1/100
163/163 [==============================] - 109s 671ms/step - loss: 0.5700
- acc: 0.7429 - val_loss: 0.8418 - val_acc: 0.5000
Epoch 82/100
162/163 [============================>.] - ETA: 0s - loss: 0.5712 - acc: 0
.7432Epoch 1/100
```

```
163/163 [==============================] - 110s 673ms/step - loss: 0.5715
- acc: 0.7429 - val_loss: 0.8273 - val_acc: 0.5000
Epoch 83/100
162/163 [============================>.] - ETA: 0s - loss: 0.5720 - acc: 0
.7427Epoch 1/100
163/163 [==============================] - 110s 675ms/step - loss: 0.5717
- acc: 0.7429 - val_loss: 0.8474 - val_acc: 0.5000
Epoch 84/100
162/163 [============================>.] - ETA: 0s - loss: 0.5721 - acc: 0
.7429Epoch 1/100
163/163 [==============================] - 110s 676ms/step - loss: 0.5721
- acc: 0.7429 - val_loss: 0.8206 - val_acc: 0.5000
Epoch 85/100
162/163 [============================>.] - ETA: 0s - loss: 0.5707 - acc: 0
.7429Epoch 1/100
163/163 [==============================] - 109s 671ms/step - loss: 0.5707
- acc: 0.7429 - val_loss: 0.8271 - val_acc: 0.5000
Epoch 86/100
162/163 [============================>.] - ETA: 0s - loss: 0.5712 - acc: 0
.7423Epoch 1/100
163/163 [==============================] - 109s 670ms/step - loss: 0.5707
- acc: 0.7429 - val_loss: 0.8174 - val_acc: 0.5000
Epoch 87/100
162/163 [============================>.] - ETA: 0s - loss: 0.5712 - acc: 0
.7432Epoch 1/100
163/163 [==============================] - 110s 673ms/step - loss: 0.5715
- acc: 0.7429 - val_loss: 0.8316 - val_acc: 0.5000
Epoch 88/100
162/163 [============================>.] - ETA: 0s - loss: 0.5714 - acc: 0
.7429Epoch 1/100
163/163 [==============================] - 109s 668ms/step - loss: 0.5714
- acc: 0.7429 - val_loss: 0.8346 - val_acc: 0.5000
Epoch 89/100
162/163 [============================>.] - ETA: 0s - loss: 0.5712 - acc: 0
.7425Epoch 1/100
163/163 [==============================] - 109s 671ms/step - loss: 0.5707
- acc: 0.7429 - val_loss: 0.8261 - val_acc: 0.5000
Epoch 90/100
162/163 [============================>.] - ETA: 0s - loss: 0.5725 - acc: 0
.7421Epoch 1/100
163/163 [==============================] - 109s 671ms/step - loss: 0.5716
- acc: 0.7429 - val_loss: 0.8343 - val_acc: 0.5000
Epoch 91/100
162/163 [============================>.] - ETA: 0s - loss: 0.5706 - acc: 0
.7432Epoch 1/100
163/163 [==============================] - 109s 667ms/step - loss: 0.5709
- acc: 0.7429 - val_loss: 0.8404 - val_acc: 0.5000
Epoch 92/100
162/163 [============================>.] - ETA: 0s - loss: 0.5703 - acc: 0
.7434Epoch 1/100
163/163 [==============================] - 110s 672ms/step - loss: 0.5708
- acc: 0.7429 - val_loss: 0.8090 - val_acc: 0.5000
Epoch 93/100
162/163 [============================>.] - ETA: 0s - loss: 0.5712 - acc: 0
```

```
.7427Epoch 1/100
163/163 [==============================] - 109s 671ms/step - loss: 0.5710
- acc: 0.7429 - val_loss: 0.8322 - val_acc: 0.5000
Epoch 94/100
162/163 [============================>.] - ETA: 0s - loss: 0.5708 - acc: 0
.7434Epoch 1/100
163/163 [==============================] - 110s 672ms/step - loss: 0.5714
- acc: 0.7429 - val_loss: 0.8245 - val_acc: 0.5000
Epoch 95/100
162/163 [============================>.] - ETA: 0s - loss: 0.5718 - acc: 0
.7429Epoch 1/100
163/163 [==============================] - 110s 674ms/step - loss: 0.5717
- acc: 0.7429 - val_loss: 0.8100 - val_acc: 0.5000
Epoch 96/100
162/163 [============================>.] - ETA: 0s - loss: 0.5713 - acc: 0
.7429Epoch 1/100
163/163 [==============================] - 109s 668ms/step - loss: 0.5713
- acc: 0.7429 - val_loss: 0.8397 - val_acc: 0.5000
Epoch 97/100
162/163 [============================>.] - ETA: 0s - loss: 0.5725 - acc: 0
.7425Epoch 1/100
163/163 [==============================] - 109s 668ms/step - loss: 0.5720
- acc: 0.7429 - val_loss: 0.8325 - val_acc: 0.5000
Epoch 98/100
162/163 [============================>.] - ETA: 0s - loss: 0.5718 - acc: 0
.7432Epoch 1/100
163/163 [==============================] - 110s 673ms/step - loss: 0.5721
- acc: 0.7429 - val_loss: 0.8177 - val_acc: 0.5000
Epoch 99/100
162/163 [============================>.] - ETA: 0s - loss: 0.5718 - acc: 0
.7432Epoch 1/100
163/163 [==============================] - 109s 672ms/step - loss: 0.5722
- acc: 0.7429 - val_loss: 0.8270 - val_acc: 0.5000
Epoch 100/100
162/163 [============================>.] - ETA: 0s - loss: 0.5712 - acc: 0
.7427Epoch 1/100
163/163 [==============================] - 110s 673ms/step - loss: 0.5710
- acc: 0.7429 - val_loss: 0.8370 - val_acc: 0.5000



--------------------------------------------------------------------------
-


modified_loss = history.history['loss'[0:100]]
modified_loss = modified_loss[1:100] #remove the first value recorded in l
oss since it's an outlier

modified_val_loss = history.history['val_loss']
modified_val_loss = modified_val_loss[1:100]

### Plot training
import matplotlib.pyplot as plt
```

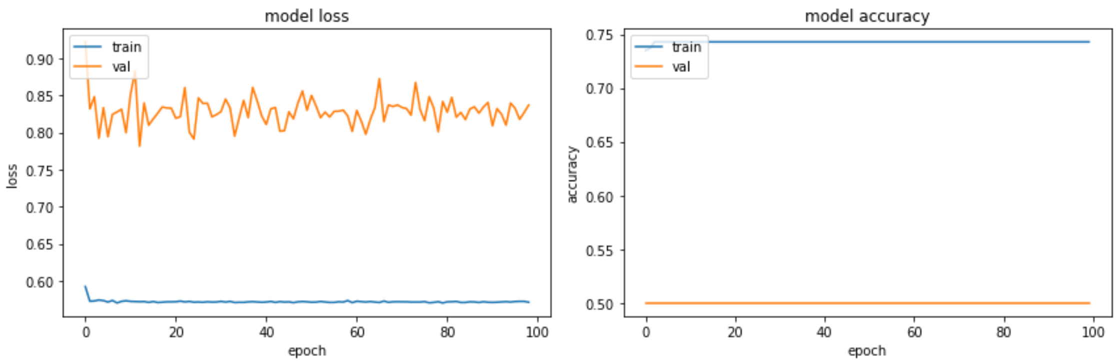
```
def plot_learning_curves(history):
    plt.figure(figsize=(12,4))

    plt.subplot(1,2,1)
    # plt.plot(history.history['loss'])
    # plt.plot(history.history['val_loss'])
    plt.plot(modified_loss) # These changes are made because of the first
record of loss is an outlier.
    plt.plot(modified_val_loss)
    plt.title('model loss')
    plt.ylabel('loss')
    plt.xlabel('epoch')
    plt.legend(['train', 'val'], loc='upper left')

    plt.subplot(1,2,2)
    plt.plot(history.history['acc'])
    plt.plot(history.history['val_acc'])
    plt.title('model accuracy')
    plt.ylabel('accuracy')
    plt.xlabel('epoch')
    plt.legend(['train', 'val'], loc='upper left')

    plt.tight_layout()

plot_learning_curves(history)
```



png

```
## Evaluate the model
test_loss, test_acc = model.evaluate_generator(generator=test_generator, v
erbose=1)

## Analytics
from sklearn.metrics import accuracy_score, confusion_matrix

test_generator.reset()
test_preds = model.predict_generator(test_generator, verbose=1)
test_preds = np.argmax(test_preds,axis=1)

acc = accuracy_score(test_generator.classes, test_preds)*100
cm = confusion_matrix(test_generator.classes, test_preds)
tn, fp, fn, tp = cm.ravel()
```

```
print('CONFUSION MATRIX ------------------')
print(cm)
# plot_confusion_matrix(cm, target_names=['NORMAL', 'PNEUMONIA'], normaliz
e=False)


print('\nTEST METRICS ----------------------')
precision = tp/(tp+fp)*100
recall = tp/(tp+fn)*100
print('Accuracy: {}%'.format(acc))
print('Precision: {}%'.format(precision))
print('Recall: {}%'.format(recall))
print('F1-score: {}'.format(2*precision*recall/(precision+recall)))

print('\nTRAIN METRIC ----------------------')
print('Train acc: {}%'.format(np.round((history.history['acc'][-1])*100, 1
4)))
```

```
20/20 [==============================] - 7s 341ms/step - loss: 0.6980 - ac
c: 0.6250
20/20 [==============================] - 7s 366ms/step
CONFUSION MATRIX ------------------
[[  0 234]
 [  0 390]]

TEST METRICS ----------------------
Accuracy: 62.5%
Precision: 62.5%
Recall: 100.0%
F1-score: 76.92307692307692

TRAIN METRIC ----------------------
Train acc: 74.29064512252808%
```

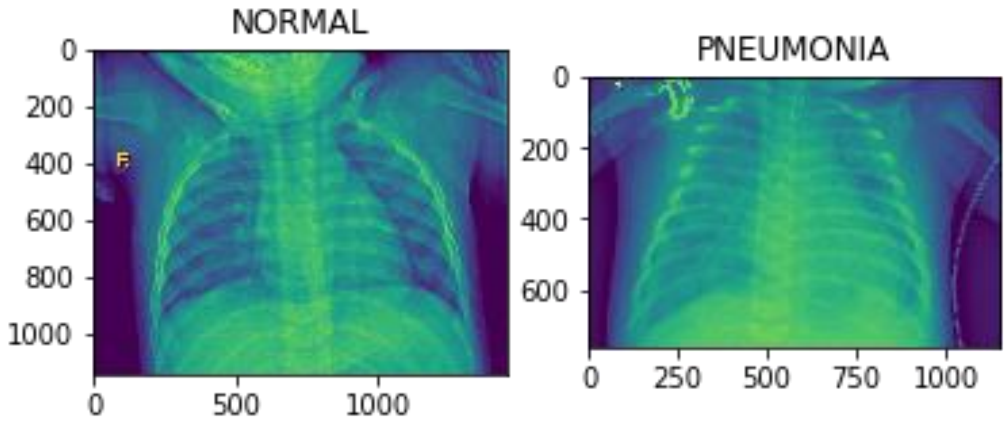
Show images

```
import matplotlib.pyplot as plt

plt.subplot(1,2,1).set_title('NORMAL')
plt.imshow(plt.imread('/content/data/chest_xray/train/NORMAL/IM-0131-0001.
jpeg'))

plt.subplot(1,2,2).set_title('PNEUMONIA')
plt.imshow(plt.imread('/content/data/chest_xray/train/PNEUMONIA/person1000
_bacteria_2931.jpeg'))
```

```
<matplotlib.image.AxesImage at 0x7f6eb0ab8908>
```


NORMAL
0
200
400
600
800
1000
0
500
1000
PNEUMONIA
0
200
400
600
0
250
500
750
1000

png

9.2 Appendix B: VGG16 Model 1 Version 1.0.1.0.0

```
from __future__ import absolute_import, division, print_function, unicode_
literals
import tensorflow as tf

# Extract dataset
import os
import tarfile

import keras_preprocessing
from keras_preprocessing.image import ImageDataGenerator # Data preprocess
ing and augmentation

import sklearn
import numpy as np
```

The default version of TensorFlow in Colab will soon switch to TensorFlow 2.x. We recommend you upgrade now or ensure your notebook will continue to use TensorFlow 1.x via the %tensorflow_version 1.x magic: more info.

```
print(tf.__version__)
```

```
1.15.0
```

```
# Make folder for chest xray data
!mkdir /content/data/

# Make directory to save weights
!mkdir /content/data/model

# Make directory to logs for Tensorboard
!mkdir /content/data/graph

# Download dataset
!wget --no-check-certificate \
    https://s3.eu-central-1.amazonaws.com/public.unit8.co/data/chest_xray.
tar.gz \
    -O /content/data/chest_xray.tar.gz

tar = tarfile.open("data/chest_xray.tar.gz")
tar.extractall(path='./data/')
os.remove('data/chest_xray.tar.gz')
```

```
--2019-10-30 03:46:42--  https://s3.eu-central-1.amazonaws.com/public.unit
8.co/data/chest_xray.tar.gz
Resolving s3.eu-central-1.amazonaws.com (s3.eu-central-1.amazonaws.com)...
52.219.74.60
Connecting to s3.eu-central-1.amazonaws.com (s3.eu-central-1.amazonaws.com
)|52.219.74.60|:443... connected.
HTTP request sent, awaiting response... 200 OK
Length: 1225393795 (1.1G) [application/x-gzip]
Saving to: ‘/content/data/chest_xray.tar.gz’
```

```
/content/data/chest 100%[==================>]   1.14G  82.2MB/s    in 13s

2019-10-30 03:46:56 (87.6 MB/s) - ‘/content/data/chest_xray.tar.gz’ saved
[1225393795/1225393795]
```

Change log:

> training_datagen –> ImageDataGenerator(NOTHING)

trainable layer –> All except base

20 layers VGG16 model - base, flat, dense

Optimizer = RMSprop(learning_rate = 0.0001)

loss = categorical_crosscentropy

callback = [checkpoints]

epochs = 100

no class weight balancing

```
TRAINING_DIR = "/content/data/chest_xray/train"
VALIDATION_DIR = "/content/data/chest_xray/val"
TEST_DIR = "/content/data/chest_xray/test"

training_datagen = ImageDataGenerator(
    # rescale = 1./255,
)

validation_datagen = ImageDataGenerator(
    # rescale = 1./255
)

test_datagen = ImageDataGenerator(
    # rescale = 1./255
)

# Create training data batch
# TODO: Try grayscaling the image to see what will happen
train_generator = training_datagen.flow_from_directory(
    TRAINING_DIR,
    class_mode='categorical'
)

validation_generator = validation_datagen.flow_from_directory(
    VALIDATION_DIR,
    class_mode='categorical'
)

test_generator = test_datagen.flow_from_directory(
    TEST_DIR,
    class_mode='categorical',
```

```
    shuffle=False
)

train_shape = train_generator.image_shape

tf.keras.backend.clear_session() # Destroys the current TF graph and creat
es a new one.

base_model = tf.keras.applications.VGG16(weights='imagenet', include_top=F
alse, input_shape=train_shape)

# Define the machine learning model
x = base_model.output
x = tf.keras.layers.Flatten()(x)
x = tf.keras.layers.Dense(2, 'softmax')(x)

model = tf.keras.Model(inputs=base_model.input, outputs=x)

# for layer in model.layers[0:20]:
#     layer.trainable = False

for layer in base_model.layers:
  layer.trainable = False

optimizer = tf.keras.optimizers.RMSprop(learning_rate=0.0001) # Lower lear
ning rate by x10

model.compile(loss='categorical_crossentropy',
              optimizer=optimizer,
              metrics=['accuracy'])

# Callbacks stuff
# Function to save the weights of the model after each epoch
checkpoint = tf.keras.callbacks.ModelCheckpoint(
    '/content/data/model/weights.epoch_{epoch:02d}.hdf5',
    monitor='val_accuracy',
    save_best_only=False,
    save_weights_only=False,
    mode='auto',
    verbose=1
)

# Function to stop training early if there's no improvement
early_stopping_monitor = tf.keras.callbacks.EarlyStopping(patience = 3, mo
nitor = "val_loss", mode="auto", verbose = 1)

lr_reduce = tf.keras.callbacks.ReduceLROnPlateau(monitor='val_loss', facto
r=0.3, patience=2, verbose=1, mode='max')

classweight = sklearn.utils.class_weight.compute_class_weight('balanced',
np.unique(train_generator.labels), train_generator.labels)
print(classweight)

batch_size = 32
```

```
epochs = 100

# Training process
history = model.fit_generator(
    generator=train_generator,
    # steps_per_epoch=train_generator.samples//batch_size,
    epochs=epochs,
    # callbacks=[early_stopping_monitor],
    callbacks=[checkpoint],
    # shuffle=True,
    validation_data=validation_generator,
    # validation_steps= validation_generator//batch_size, #no because it's
gonna be 0... if leave alone its len(generator) which is equal to 1.
    # class_weight=classweight,
    verbose = 1
)

# test_loss, test_acc = model.evaluate_generator(generator=test_generator,
verbose=1)

### Plot training
import matplotlib.pyplot as plt
def plot_learning_curves(history):
    plt.figure(figsize=(12,4))

    plt.subplot(1,2,1)
    plt.plot(history.history['loss'])
    plt.plot(history.history['val_loss'])
    plt.title('model loss')
    plt.ylabel('loss')
    plt.xlabel('epoch')
    plt.legend(['train', 'val'], loc='upper left')

    plt.subplot(1,2,2)
    plt.plot(history.history['acc'])
    plt.plot(history.history['val_acc'])
    plt.title('model accuracy')
    plt.ylabel('accuracy')
    plt.xlabel('epoch')
    plt.legend(['train', 'val'], loc='upper left')

    plt.tight_layout()

plot_learning_curves(history)

## Load best weight
idx = np.argmin(history.history['val_loss'])
model.load_weights("/content/data/model/weights.epoch_{:02d}.hdf5".format(
idx + 1))

print("Loading the best model")
print("epoch: {}, val_loss: {}, val_acc: {}".format(idx + 1, history.histo
ry['val_loss'][idx], history.history['val_acc'][idx]))
```

```
## Evaluate the model
test_loss, test_acc = model.evaluate_generator(generator=test_generator, v
erbose=1)

## Analytics
from sklearn.metrics import accuracy_score, confusion_matrix

test_generator.reset()
test_preds = model.predict_generator(test_generator, verbose=1)
test_preds = np.argmax(test_preds,axis=1)

acc = accuracy_score(test_generator.classes, test_preds)*100
cm = confusion_matrix(test_generator.classes, test_preds)
tn, fp, fn, tp = cm.ravel()

print('CONFUSION MATRIX ------------------')
print(cm)
# plot_confusion_matrix(cm, target_names=['NORMAL', 'PNEUMONIA'], normaliz
e=False)


print('\nTEST METRICS ----------------------')
precision = tp/(tp+fp)*100
recall = tp/(tp+fn)*100
print('Accuracy: {}%'.format(acc))
print('Precision: {}%'.format(precision))
print('Recall: {}%'.format(recall))
print('F1-score: {}'.format(2*precision*recall/(precision+recall)))

print('\nTRAIN METRIC ----------------------')
print('Train acc: {}%'.format(np.round((history.history['acc'][-1])*100, 1
4)))
```

```
Found 5216 images belonging to 2 classes.
Found 16 images belonging to 2 classes.
Found 624 images belonging to 2 classes.
WARNING:tensorflow:From /usr/local/lib/python3.6/dist-packages/tensorflow_
core/python/ops/resource_variable_ops.py:1630: calling BaseResourceVariabl
e.__init__ (from tensorflow.python.ops.resource_variable_ops) with constra
int is deprecated and will be removed in a future version.
Instructions for updating:
If using Keras pass *_constraint arguments to layers.
Downloading data from https://github.com/fchollet/deep-learning-models/rel
eases/download/v0.1/vgg16_weights_tf_dim_ordering_tf_kernels_notop.h5
58892288/58889256 [==============================] - 3s 0us/step
[1.9448173  0.67303226]
Epoch 1/100
162/163 [============================>.] - ETA: 0s - loss: 0.6576 - acc: 0
.9302Epoch 1/100
  1/163 [..............................] - ETA: 7:06 - loss: 3.4501e-04 -
acc: 1.0000
Epoch 00001: saving model to /content/data/model/weights.epoch_01.hdf5
163/163 [==============================] - 82s 502ms/step - loss: 0.6575 -
acc: 0.9304 - val_loss: 3.4501e-04 - val_acc: 1.0000
```

```
Epoch 2/100
162/163 [============================>.] - ETA: 0s - loss: 0.1611 - acc: 0
.9770Epoch 1/100
  1/163 [..............................] - ETA: 1:15 - loss: 0.0131 - acc:
1.0000
Epoch 00002: saving model to /content/data/model/weights.epoch_02.hdf5
163/163 [==============================] - 74s 455ms/step - loss: 0.1609 -
acc: 0.9770 - val_loss: 0.0131 - val_acc: 1.0000
Epoch 3/100
162/163 [============================>.] - ETA: 0s - loss: 0.0772 - acc: 0
.9880Epoch 1/100
  1/163 [..............................] - ETA: 1:13 - loss: 0.1195 - acc:
0.9375
Epoch 00003: saving model to /content/data/model/weights.epoch_03.hdf5
163/163 [==============================] - 76s 466ms/step - loss: 0.0767 -
acc: 0.9881 - val_loss: 0.1195 - val_acc: 0.9375
Epoch 4/100
162/163 [============================>.] - ETA: 0s - loss: 0.0499 - acc: 0
.9929Epoch 1/100
  1/163 [..............................] - ETA: 1:14 - loss: 0.0029 - acc:
1.0000
Epoch 00004: saving model to /content/data/model/weights.epoch_04.hdf5
163/163 [==============================] - 76s 464ms/step - loss: 0.0496 -
acc: 0.9929 - val_loss: 0.0029 - val_acc: 1.0000
Epoch 5/100
162/163 [============================>.] - ETA: 0s - loss: 0.0090 - acc: 0
.9977Epoch 1/100
  1/163 [..............................] - ETA: 1:15 - loss: 0.0301 - acc:
1.0000
Epoch 00005: saving model to /content/data/model/weights.epoch_05.hdf5
163/163 [==============================] - 76s 465ms/step - loss: 0.0090 -
acc: 0.9977 - val_loss: 0.0301 - val_acc: 1.0000
Epoch 6/100
162/163 [============================>.] - ETA: 0s - loss: 0.0182 - acc: 0
.9979Epoch 1/100
  1/163 [..............................] - ETA: 1:13 - loss: 0.0280 - acc:
1.0000
Epoch 00006: saving model to /content/data/model/weights.epoch_06.hdf5
163/163 [==============================] - 75s 460ms/step - loss: 0.0181 -
acc: 0.9979 - val_loss: 0.0280 - val_acc: 1.0000
Epoch 7/100
162/163 [============================>.] - ETA: 0s - loss: 0.0011 - acc: 0
.9998Epoch 1/100
  1/163 [..............................] - ETA: 1:15 - loss: 0.0024 - acc:
1.0000
Epoch 00007: saving model to /content/data/model/weights.epoch_07.hdf5
163/163 [==============================] - 76s 466ms/step - loss: 0.0011 -
acc: 0.9998 - val_loss: 0.0024 - val_acc: 1.0000
Epoch 8/100
162/163 [============================>.] - ETA: 0s - loss: 0.0048 - acc: 0
.9983Epoch 1/100
  1/163 [..............................] - ETA: 1:15 - loss: 0.1892 - acc:
0.9375
Epoch 00008: saving model to /content/data/model/weights.epoch_08.hdf5
```

```
163/163 [==============================] - 76s 464ms/step - loss: 0.0047 -
acc: 0.9983 - val_loss: 0.1892 - val_acc: 0.9375
Epoch 9/100
162/163 [============================>.] - ETA: 0s - loss: 0.0029 - acc: 0
.9988Epoch 1/100
  1/163 [..............................] - ETA: 1:13 - loss: 0.0028 - acc:
1.0000
Epoch 00009: saving model to /content/data/model/weights.epoch_09.hdf5
163/163 [==============================] - 76s 464ms/step - loss: 0.0029 -
acc: 0.9988 - val_loss: 0.0028 - val_acc: 1.0000
Epoch 10/100
162/163 [============================>.] - ETA: 0s - loss: 0.0046 - acc: 0
.9994Epoch 1/100
  1/163 [..............................] - ETA: 1:15 - loss: 0.0072 - acc:
1.0000
Epoch 00010: saving model to /content/data/model/weights.epoch_10.hdf5
163/163 [==============================] - 75s 463ms/step - loss: 0.0046 -
acc: 0.9994 - val_loss: 0.0072 - val_acc: 1.0000
Epoch 11/100
162/163 [============================>.] - ETA: 0s - loss: 0.0012 - acc: 0
.9994Epoch 1/100
  1/163 [..............................] - ETA: 1:13 - loss: 3.2180e-04 -
acc: 1.0000
Epoch 00011: saving model to /content/data/model/weights.epoch_11.hdf5
163/163 [==============================] - 76s 464ms/step - loss: 0.0012 -
acc: 0.9994 - val_loss: 3.2180e-04 - val_acc: 1.0000
Epoch 12/100
162/163 [============================>.] - ETA: 0s - loss: 0.0025 - acc: 0
.9990Epoch 1/100
  1/163 [..............................] - ETA: 1:19 - loss: 5.0857e-04 -
acc: 1.0000
Epoch 00012: saving model to /content/data/model/weights.epoch_12.hdf5
163/163 [==============================] - 76s 469ms/step - loss: 0.0027 -
acc: 0.9988 - val_loss: 5.0857e-04 - val_acc: 1.0000
Epoch 13/100
162/163 [============================>.] - ETA: 0s - loss: 1.0987e-04 - ac
c: 1.0000Epoch 1/100
  1/163 [..............................] - ETA: 1:12 - loss: 2.7596e-04 -
acc: 1.0000
Epoch 00013: saving model to /content/data/model/weights.epoch_13.hdf5
163/163 [==============================] - 76s 469ms/step - loss: 1.0920e-
04 - acc: 1.0000 - val_loss: 2.7596e-04 - val_acc: 1.0000
Epoch 14/100
162/163 [============================>.] - ETA: 0s - loss: 2.6691e-07 - ac
c: 1.0000Epoch 1/100
  1/163 [..............................] - ETA: 1:14 - loss: 6.7055e-08 -
acc: 1.0000
Epoch 00014: saving model to /content/data/model/weights.epoch_14.hdf5
163/163 [==============================] - 76s 468ms/step - loss: 2.6527e-
07 - acc: 1.0000 - val_loss: 6.7055e-08 - val_acc: 1.0000
Epoch 15/100
162/163 [============================>.] - ETA: 0s - loss: 0.0047 - acc: 0
.9992Epoch 1/100
  1/163 [..............................] - ETA: 1:15 - loss: 5.7648e-05 -
```

```
acc: 1.0000
Epoch 00015: saving model to /content/data/model/weights.epoch_15.hdf5
163/163 [==============================] - 77s 471ms/step - loss: 0.0046 -
acc: 0.9992 - val_loss: 5.7648e-05 - val_acc: 1.0000
Epoch 16/100
162/163 [============================>.] - ETA: 0s - loss: 1.1142e-05 - ac
c: 1.0000Epoch 1/100
  1/163 [..............................] - ETA: 1:13 - loss: 0.0043 - acc:
1.0000
Epoch 00016: saving model to /content/data/model/weights.epoch_16.hdf5
163/163 [==============================] - 76s 469ms/step - loss: 1.1073e-
05 - acc: 1.0000 - val_loss: 0.0043 - val_acc: 1.0000
Epoch 17/100
162/163 [============================>.] - ETA: 0s - loss: 6.5034e-04 - ac
c: 0.9996Epoch 1/100
  1/163 [..............................] - ETA: 1:15 - loss: 2.5331e-06 -
acc: 1.0000
Epoch 00017: saving model to /content/data/model/weights.epoch_17.hdf5
163/163 [==============================] - 76s 468ms/step - loss: 6.4640e-
04 - acc: 0.9996 - val_loss: 2.5331e-06 - val_acc: 1.0000
Epoch 18/100
162/163 [============================>.] - ETA: 0s - loss: 2.0865e-04 - ac
c: 1.0000Epoch 1/100
  1/163 [..............................] - ETA: 1:12 - loss: 0.0014 - acc:
1.0000
Epoch 00018: saving model to /content/data/model/weights.epoch_18.hdf5
163/163 [==============================] - 76s 464ms/step - loss: 2.0737e-
04 - acc: 1.0000 - val_loss: 0.0014 - val_acc: 1.0000
Epoch 19/100
162/163 [============================>.] - ETA: 0s - loss: 0.0021 - acc: 0
.9998Epoch 1/100
  1/163 [..............................] - ETA: 1:15 - loss: 9.7460e-05 -
acc: 1.0000
Epoch 00019: saving model to /content/data/model/weights.epoch_19.hdf5
163/163 [==============================] - 75s 461ms/step - loss: 0.0021 -
acc: 0.9998 - val_loss: 9.7460e-05 - val_acc: 1.0000
Epoch 20/100
162/163 [============================>.] - ETA: 0s - loss: 1.8856e-09 - ac
c: 1.0000Epoch 1/100
  1/163 [..............................] - ETA: 1:17 - loss: 2.2273e-04 -
acc: 1.0000
Epoch 00020: saving model to /content/data/model/weights.epoch_20.hdf5
163/163 [==============================] - 77s 474ms/step - loss: 1.8741e-
09 - acc: 1.0000 - val_loss: 2.2273e-04 - val_acc: 1.0000
Epoch 21/100
162/163 [============================>.] - ETA: 0s - loss: 6.7991e-05 - ac
c: 1.0000Epoch 1/100
  1/163 [..............................] - ETA: 1:16 - loss: 0.0095 - acc:
1.0000
Epoch 00021: saving model to /content/data/model/weights.epoch_21.hdf5
163/163 [==============================] - 76s 468ms/step - loss: 6.7574e-
05 - acc: 1.0000 - val_loss: 0.0095 - val_acc: 1.0000
Epoch 22/100
162/163 [============================>.] - ETA: 0s - loss: 1.2153e-05 - ac
```

```
c: 1.0000Epoch 1/100
  1/163 [..............................] - ETA: 1:12 - loss: 0.0028 - acc:
1.0000
Epoch 00022: saving model to /content/data/model/weights.epoch_22.hdf5
163/163 [==============================] - 76s 468ms/step - loss: 1.2078e-
05 - acc: 1.0000 - val_loss: 0.0028 - val_acc: 1.0000
Epoch 23/100
162/163 [============================>.] - ETA: 0s - loss: 1.5637e-09 - ac
c: 1.0000Epoch 1/100
  1/163 [..............................] - ETA: 1:13 - loss: 8.6583e-04 -
acc: 1.0000
Epoch 00023: saving model to /content/data/model/weights.epoch_23.hdf5
163/163 [==============================] - 76s 464ms/step - loss: 1.5541e-
09 - acc: 1.0000 - val_loss: 8.6583e-04 - val_acc: 1.0000
Epoch 24/100
162/163 [============================>.] - ETA: 0s - loss: 0.0000e+00 - ac
c: 1.0000Epoch 1/100
  1/163 [..............................] - ETA: 1:11 - loss: 0.0017 - acc:
1.0000
Epoch 00024: saving model to /content/data/model/weights.epoch_24.hdf5
163/163 [==============================] - 76s 463ms/step - loss: 0.0000e+
00 - acc: 1.0000 - val_loss: 0.0017 - val_acc: 1.0000
Epoch 25/100
162/163 [============================>.] - ETA: 0s - loss: 0.0000e+00 - ac
c: 1.0000Epoch 1/100
  1/163 [..............................] - ETA: 1:13 - loss: 0.0028 - acc:
1.0000
Epoch 00025: saving model to /content/data/model/weights.epoch_25.hdf5
163/163 [==============================] - 75s 460ms/step - loss: 0.0000e+
00 - acc: 1.0000 - val_loss: 0.0028 - val_acc: 1.0000
Epoch 26/100
162/163 [============================>.] - ETA: 0s - loss: 0.0000e+00 - ac
c: 1.0000Epoch 1/100
  1/163 [..............................] - ETA: 1:14 - loss: 0.0036 - acc:
1.0000
Epoch 00026: saving model to /content/data/model/weights.epoch_26.hdf5
163/163 [==============================] - 77s 471ms/step - loss: 0.0000e+
00 - acc: 1.0000 - val_loss: 0.0036 - val_acc: 1.0000
Epoch 27/100
162/163 [============================>.] - ETA: 0s - loss: 0.0000e+00 - ac
c: 1.0000Epoch 1/100
  1/163 [..............................] - ETA: 1:15 - loss: 0.0032 - acc:
1.0000
Epoch 00027: saving model to /content/data/model/weights.epoch_27.hdf5
163/163 [==============================] - 77s 473ms/step - loss: 0.0000e+
00 - acc: 1.0000 - val_loss: 0.0032 - val_acc: 1.0000
Epoch 28/100
162/163 [============================>.] - ETA: 0s - loss: 0.0000e+00 - ac
c: 1.0000Epoch 1/100
  1/163 [..............................] - ETA: 1:10 - loss: 0.0041 - acc:
1.0000
Epoch 00028: saving model to /content/data/model/weights.epoch_28.hdf5
163/163 [==============================] - 78s 478ms/step - loss: 0.0000e+
00 - acc: 1.0000 - val_loss: 0.0041 - val_acc: 1.0000
```

```
Epoch 29/100
162/163 [============================>.] - ETA: 0s - loss: 0.0000e+00 - ac
c: 1.0000Epoch 1/100
  1/163 [..............................] - ETA: 1:14 - loss: 0.0046 - acc:
1.0000
Epoch 00029: saving model to /content/data/model/weights.epoch_29.hdf5
163/163 [==============================] - 77s 472ms/step - loss: 0.0000e+
00 - acc: 1.0000 - val_loss: 0.0046 - val_acc: 1.0000
Epoch 30/100
162/163 [============================>.] - ETA: 0s - loss: 0.0000e+00 - ac
c: 1.0000Epoch 1/100
  1/163 [..............................] - ETA: 1:13 - loss: 0.0060 - acc:
1.0000
Epoch 00030: saving model to /content/data/model/weights.epoch_30.hdf5
163/163 [==============================] - 76s 465ms/step - loss: 0.0000e+
00 - acc: 1.0000 - val_loss: 0.0060 - val_acc: 1.0000
Epoch 31/100
162/163 [============================>.] - ETA: 0s - loss: 0.0000e+00 - ac
c: 1.0000Epoch 1/100
  1/163 [..............................] - ETA: 1:14 - loss: 0.0047 - acc:
1.0000
Epoch 00031: saving model to /content/data/model/weights.epoch_31.hdf5
163/163 [==============================] - 76s 464ms/step - loss: 0.0000e+
00 - acc: 1.0000 - val_loss: 0.0047 - val_acc: 1.0000
Epoch 32/100
162/163 [============================>.] - ETA: 0s - loss: 0.0000e+00 - ac
c: 1.0000Epoch 1/100
  1/163 [..............................] - ETA: 1:14 - loss: 0.0040 - acc:
1.0000
Epoch 00032: saving model to /content/data/model/weights.epoch_32.hdf5
163/163 [==============================] - 78s 481ms/step - loss: 0.0000e+
00 - acc: 1.0000 - val_loss: 0.0040 - val_acc: 1.0000
Epoch 33/100
162/163 [============================>.] - ETA: 0s - loss: 0.0000e+00 - ac
c: 1.0000Epoch 1/100
  1/163 [..............................] - ETA: 1:13 - loss: 0.0039 - acc:
1.0000
Epoch 00033: saving model to /content/data/model/weights.epoch_33.hdf5
163/163 [==============================] - 77s 470ms/step - loss: 0.0000e+
00 - acc: 1.0000 - val_loss: 0.0039 - val_acc: 1.0000
Epoch 34/100
162/163 [============================>.] - ETA: 0s - loss: 0.0000e+00 - ac
c: 1.0000Epoch 1/100
  1/163 [..............................] - ETA: 1:16 - loss: 0.0041 - acc:
1.0000
Epoch 00034: saving model to /content/data/model/weights.epoch_34.hdf5
163/163 [==============================] - 76s 465ms/step - loss: 0.0000e+
00 - acc: 1.0000 - val_loss: 0.0041 - val_acc: 1.0000
Epoch 35/100
162/163 [============================>.] - ETA: 0s - loss: 0.0000e+00 - ac
c: 1.0000Epoch 1/100
  1/163 [..............................] - ETA: 1:12 - loss: 0.0056 - acc:
1.0000
Epoch 00035: saving model to /content/data/model/weights.epoch_35.hdf5
```

```
163/163 [==============================] - 75s 460ms/step - loss: 0.0000e+
00 - acc: 1.0000 - val_loss: 0.0056 - val_acc: 1.0000
Epoch 36/100
162/163 [============================>.] - ETA: 0s - loss: 0.0000e+00 - ac
c: 1.0000Epoch 1/100
  1/163 [..............................] - ETA: 1:12 - loss: 0.0046 - acc:
1.0000
Epoch 00036: saving model to /content/data/model/weights.epoch_36.hdf5
163/163 [==============================] - 76s 464ms/step - loss: 0.0000e+
00 - acc: 1.0000 - val_loss: 0.0046 - val_acc: 1.0000
Epoch 37/100
162/163 [============================>.] - ETA: 0s - loss: 0.0000e+00 - ac
c: 1.0000Epoch 1/100
  1/163 [..............................] - ETA: 1:15 - loss: 0.0052 - acc:
1.0000
Epoch 00037: saving model to /content/data/model/weights.epoch_37.hdf5
163/163 [==============================] - 76s 465ms/step - loss: 0.0000e+
00 - acc: 1.0000 - val_loss: 0.0052 - val_acc: 1.0000
Epoch 38/100
162/163 [============================>.] - ETA: 0s - loss: 0.0000e+00 - ac
c: 1.0000Epoch 1/100
  1/163 [..............................] - ETA: 1:18 - loss: 0.0049 - acc:
1.0000
Epoch 00038: saving model to /content/data/model/weights.epoch_38.hdf5
163/163 [==============================] - 78s 476ms/step - loss: 0.0000e+
00 - acc: 1.0000 - val_loss: 0.0049 - val_acc: 1.0000
Epoch 39/100
162/163 [============================>.] - ETA: 0s - loss: 0.0000e+00 - ac
c: 1.0000Epoch 1/100
  1/163 [..............................] - ETA: 1:17 - loss: 0.0045 - acc:
1.0000
Epoch 00039: saving model to /content/data/model/weights.epoch_39.hdf5
163/163 [==============================] - 75s 463ms/step - loss: 0.0000e+
00 - acc: 1.0000 - val_loss: 0.0045 - val_acc: 1.0000
Epoch 40/100
162/163 [============================>.] - ETA: 0s - loss: 0.0000e+00 - ac
c: 1.0000Epoch 1/100
  1/163 [..............................] - ETA: 1:13 - loss: 0.0055 - acc:
1.0000
Epoch 00040: saving model to /content/data/model/weights.epoch_40.hdf5
163/163 [==============================] - 78s 478ms/step - loss: 0.0000e+
00 - acc: 1.0000 - val_loss: 0.0055 - val_acc: 1.0000
Epoch 41/100
162/163 [============================>.] - ETA: 0s - loss: 0.0000e+00 - ac
c: 1.0000Epoch 1/100
  1/163 [..............................] - ETA: 1:13 - loss: 0.0055 - acc:
1.0000
Epoch 00041: saving model to /content/data/model/weights.epoch_41.hdf5
163/163 [==============================] - 76s 466ms/step - loss: 0.0000e+
00 - acc: 1.0000 - val_loss: 0.0055 - val_acc: 1.0000
Epoch 42/100
162/163 [============================>.] - ETA: 0s - loss: 0.0000e+00 - ac
c: 1.0000Epoch 1/100
  1/163 [..............................] - ETA: 1:17 - loss: 0.0042 - acc:
```

```
1.0000
Epoch 00042: saving model to /content/data/model/weights.epoch_42.hdf5
163/163 [==============================] - 78s 481ms/step - loss: 0.0000e+
00 - acc: 1.0000 - val_loss: 0.0042 - val_acc: 1.0000
Epoch 43/100
162/163 [============================>.] - ETA: 0s - loss: 0.0000e+00 - ac
c: 1.0000Epoch 1/100
  1/163 [..............................] - ETA: 1:15 - loss: 0.0044 - acc:
1.0000
Epoch 00043: saving model to /content/data/model/weights.epoch_43.hdf5
163/163 [==============================] - 78s 480ms/step - loss: 0.0000e+
00 - acc: 1.0000 - val_loss: 0.0044 - val_acc: 1.0000
Epoch 44/100
162/163 [============================>.] - ETA: 0s - loss: 0.0000e+00 - ac
c: 1.0000Epoch 1/100
  1/163 [..............................] - ETA: 1:10 - loss: 0.0048 - acc:
1.0000
Epoch 00044: saving model to /content/data/model/weights.epoch_44.hdf5
163/163 [==============================] - 77s 470ms/step - loss: 0.0000e+
00 - acc: 1.0000 - val_loss: 0.0048 - val_acc: 1.0000
Epoch 45/100
162/163 [============================>.] - ETA: 0s - loss: 0.0000e+00 - ac
c: 1.0000Epoch 1/100
  1/163 [..............................] - ETA: 1:13 - loss: 0.0047 - acc:
1.0000
Epoch 00045: saving model to /content/data/model/weights.epoch_45.hdf5
163/163 [==============================] - 76s 463ms/step - loss: 0.0000e+
00 - acc: 1.0000 - val_loss: 0.0047 - val_acc: 1.0000
Epoch 46/100
162/163 [============================>.] - ETA: 0s - loss: 0.0000e+00 - ac
c: 1.0000Epoch 1/100
  1/163 [..............................] - ETA: 1:14 - loss: 0.0048 - acc:
1.0000
Epoch 00046: saving model to /content/data/model/weights.epoch_46.hdf5
163/163 [==============================] - 76s 468ms/step - loss: 0.0000e+
00 - acc: 1.0000 - val_loss: 0.0048 - val_acc: 1.0000
Epoch 47/100
162/163 [============================>.] - ETA: 0s - loss: 0.0000e+00 - ac
c: 1.0000Epoch 1/100
  1/163 [..............................] - ETA: 1:16 - loss: 0.0050 - acc:
1.0000
Epoch 00047: saving model to /content/data/model/weights.epoch_47.hdf5
163/163 [==============================] - 78s 479ms/step - loss: 0.0000e+
00 - acc: 1.0000 - val_loss: 0.0050 - val_acc: 1.0000
Epoch 48/100
162/163 [============================>.] - ETA: 0s - loss: 0.0000e+00 - ac
c: 1.0000Epoch 1/100
  1/163 [..............................] - ETA: 1:15 - loss: 0.0052 - acc:
1.0000
Epoch 00048: saving model to /content/data/model/weights.epoch_48.hdf5
163/163 [==============================] - 78s 481ms/step - loss: 0.0000e+
00 - acc: 1.0000 - val_loss: 0.0052 - val_acc: 1.0000
Epoch 49/100
162/163 [============================>.] - ETA: 0s - loss: 0.0000e+00 - ac
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c: 1.0000Epoch 1/100
  1/163 [..............................] - ETA: 1:13 - loss: 0.0046 - acc:
1.0000
Epoch 00049: saving model to /content/data/model/weights.epoch_49.hdf5
163/163 [==============================] - 76s 468ms/step - loss: 0.0000e+
00 - acc: 1.0000 - val_loss: 0.0046 - val_acc: 1.0000
Epoch 50/100
162/163 [============================>.] - ETA: 0s - loss: 0.0000e+00 - ac
c: 1.0000Epoch 1/100
  1/163 [..............................] - ETA: 1:17 - loss: 0.0047 - acc:
1.0000
Epoch 00050: saving model to /content/data/model/weights.epoch_50.hdf5
163/163 [==============================] - 76s 464ms/step - loss: 0.0000e+
00 - acc: 1.0000 - val_loss: 0.0047 - val_acc: 1.0000
Epoch 51/100
162/163 [============================>.] - ETA: 0s - loss: 0.0000e+00 - ac
c: 1.0000Epoch 1/100
  1/163 [..............................] - ETA: 1:10 - loss: 0.0048 - acc:
1.0000
Epoch 00051: saving model to /content/data/model/weights.epoch_51.hdf5
163/163 [==============================] - 75s 461ms/step - loss: 0.0000e+
00 - acc: 1.0000 - val_loss: 0.0048 - val_acc: 1.0000
Epoch 52/100
162/163 [============================>.] - ETA: 0s - loss: 0.0000e+00 - ac
c: 1.0000Epoch 1/100
  1/163 [..............................] - ETA: 1:15 - loss: 0.0045 - acc:
1.0000
Epoch 00052: saving model to /content/data/model/weights.epoch_52.hdf5
163/163 [==============================] - 76s 466ms/step - loss: 0.0000e+
00 - acc: 1.0000 - val_loss: 0.0045 - val_acc: 1.0000
Epoch 53/100
162/163 [============================>.] - ETA: 0s - loss: 0.0000e+00 - ac
c: 1.0000Epoch 1/100
  1/163 [..............................] - ETA: 1:13 - loss: 0.0054 - acc:
1.0000
Epoch 00053: saving model to /content/data/model/weights.epoch_53.hdf5
163/163 [==============================] - 77s 472ms/step - loss: 0.0000e+
00 - acc: 1.0000 - val_loss: 0.0054 - val_acc: 1.0000
Epoch 54/100
162/163 [============================>.] - ETA: 0s - loss: 0.0000e+00 - ac
c: 1.0000Epoch 1/100
  1/163 [..............................] - ETA: 1:15 - loss: 0.0049 - acc:
1.0000
Epoch 00054: saving model to /content/data/model/weights.epoch_54.hdf5
163/163 [==============================] - 77s 473ms/step - loss: 0.0000e+
00 - acc: 1.0000 - val_loss: 0.0049 - val_acc: 1.0000
Epoch 55/100
162/163 [============================>.] - ETA: 0s - loss: 0.0000e+00 - ac
c: 1.0000Epoch 1/100
  1/163 [..............................] - ETA: 1:16 - loss: 0.0047 - acc:
1.0000
Epoch 00055: saving model to /content/data/model/weights.epoch_55.hdf5
163/163 [==============================] - 78s 478ms/step - loss: 0.0000e+
00 - acc: 1.0000 - val_loss: 0.0047 - val_acc: 1.0000
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Epoch 56/100
162/163 [============================>.] - ETA: 0s - loss: 0.0000e+00 - ac
c: 1.0000Epoch 1/100
  1/163 [..............................] - ETA: 1:14 - loss: 0.0050 - acc:
1.0000
Epoch 00056: saving model to /content/data/model/weights.epoch_56.hdf5
163/163 [==============================] - 78s 478ms/step - loss: 0.0000e+
00 - acc: 1.0000 - val_loss: 0.0050 - val_acc: 1.0000
Epoch 57/100
162/163 [============================>.] - ETA: 0s - loss: 0.0000e+00 - ac
c: 1.0000Epoch 1/100
  1/163 [..............................] - ETA: 1:14 - loss: 0.0052 - acc:
1.0000
Epoch 00057: saving model to /content/data/model/weights.epoch_57.hdf5
163/163 [==============================] - 76s 466ms/step - loss: 0.0000e+
00 - acc: 1.0000 - val_loss: 0.0052 - val_acc: 1.0000
Epoch 58/100
162/163 [============================>.] - ETA: 0s - loss: 0.0000e+00 - ac
c: 1.0000Epoch 1/100
  1/163 [..............................] - ETA: 1:15 - loss: 0.0045 - acc:
1.0000
Epoch 00058: saving model to /content/data/model/weights.epoch_58.hdf5
163/163 [==============================] - 75s 461ms/step - loss: 0.0000e+
00 - acc: 1.0000 - val_loss: 0.0045 - val_acc: 1.0000
Epoch 59/100
162/163 [============================>.] - ETA: 0s - loss: 0.0000e+00 - ac
c: 1.0000Epoch 1/100
  1/163 [..............................] - ETA: 1:13 - loss: 0.0055 - acc:
1.0000
Epoch 00059: saving model to /content/data/model/weights.epoch_59.hdf5
163/163 [==============================] - 75s 461ms/step - loss: 0.0000e+
00 - acc: 1.0000 - val_loss: 0.0055 - val_acc: 1.0000
Epoch 60/100
162/163 [============================>.] - ETA: 0s - loss: 0.0000e+00 - ac
c: 1.0000Epoch 1/100
  1/163 [..............................] - ETA: 1:14 - loss: 0.0052 - acc:
1.0000
Epoch 00060: saving model to /content/data/model/weights.epoch_60.hdf5
163/163 [==============================] - 75s 463ms/step - loss: 0.0000e+
00 - acc: 1.0000 - val_loss: 0.0052 - val_acc: 1.0000
Epoch 61/100
162/163 [============================>.] - ETA: 0s - loss: 0.0000e+00 - ac
c: 1.0000Epoch 1/100
  1/163 [..............................] - ETA: 1:13 - loss: 0.0047 - acc:
1.0000
Epoch 00061: saving model to /content/data/model/weights.epoch_61.hdf5
163/163 [==============================] - 76s 465ms/step - loss: 0.0000e+
00 - acc: 1.0000 - val_loss: 0.0047 - val_acc: 1.0000
Epoch 62/100
162/163 [============================>.] - ETA: 0s - loss: 0.0000e+00 - ac
c: 1.0000Epoch 1/100
  1/163 [..............................] - ETA: 1:11 - loss: 0.0047 - acc:
1.0000
Epoch 00062: saving model to /content/data/model/weights.epoch_62.hdf5
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163/163 [==============================] - 75s 460ms/step - loss: 0.0000e+
00 - acc: 1.0000 - val_loss: 0.0047 - val_acc: 1.0000
Epoch 63/100
162/163 [============================>.] - ETA: 0s - loss: 0.0000e+00 - ac
c: 1.0000Epoch 1/100
  1/163 [..............................] - ETA: 1:14 - loss: 0.0049 - acc:
1.0000
Epoch 00063: saving model to /content/data/model/weights.epoch_63.hdf5
163/163 [==============================] - 75s 463ms/step - loss: 0.0000e+
00 - acc: 1.0000 - val_loss: 0.0049 - val_acc: 1.0000
Epoch 64/100
162/163 [============================>.] - ETA: 0s - loss: 0.0000e+00 - ac
c: 1.0000Epoch 1/100
  1/163 [..............................] - ETA: 1:13 - loss: 0.0047 - acc:
1.0000
Epoch 00064: saving model to /content/data/model/weights.epoch_64.hdf5
163/163 [==============================] - 75s 459ms/step - loss: 0.0000e+
00 - acc: 1.0000 - val_loss: 0.0047 - val_acc: 1.0000
Epoch 65/100
162/163 [============================>.] - ETA: 0s - loss: 0.0000e+00 - ac
c: 1.0000Epoch 1/100
  1/163 [..............................] - ETA: 1:13 - loss: 0.0052 - acc:
1.0000
Epoch 00065: saving model to /content/data/model/weights.epoch_65.hdf5
163/163 [==============================] - 75s 461ms/step - loss: 0.0000e+
00 - acc: 1.0000 - val_loss: 0.0052 - val_acc: 1.0000
Epoch 66/100
162/163 [============================>.] - ETA: 0s - loss: 0.0000e+00 - ac
c: 1.0000Epoch 1/100
  1/163 [..............................] - ETA: 1:14 - loss: 0.0046 - acc:
1.0000
Epoch 00066: saving model to /content/data/model/weights.epoch_66.hdf5
163/163 [==============================] - 75s 463ms/step - loss: 0.0000e+
00 - acc: 1.0000 - val_loss: 0.0046 - val_acc: 1.0000
Epoch 67/100
162/163 [============================>.] - ETA: 0s - loss: 0.0000e+00 - ac
c: 1.0000Epoch 1/100
  1/163 [..............................] - ETA: 1:11 - loss: 0.0046 - acc:
1.0000
Epoch 00067: saving model to /content/data/model/weights.epoch_67.hdf5
163/163 [==============================] - 76s 468ms/step - loss: 0.0000e+
00 - acc: 1.0000 - val_loss: 0.0046 - val_acc: 1.0000
Epoch 68/100
162/163 [============================>.] - ETA: 0s - loss: 0.0000e+00 - ac
c: 1.0000Epoch 1/100
  1/163 [..............................] - ETA: 1:12 - loss: 0.0050 - acc:
1.0000
Epoch 00068: saving model to /content/data/model/weights.epoch_68.hdf5
163/163 [==============================] - 77s 471ms/step - loss: 0.0000e+
00 - acc: 1.0000 - val_loss: 0.0050 - val_acc: 1.0000
Epoch 69/100
162/163 [============================>.] - ETA: 0s - loss: 0.0000e+00 - ac
c: 1.0000Epoch 1/100
  1/163 [..............................] - ETA: 1:13 - loss: 0.0050 - acc:
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1.0000
Epoch 00069: saving model to /content/data/model/weights.epoch_69.hdf5
163/163 [==============================] - 76s 464ms/step - loss: 0.0000e+
00 - acc: 1.0000 - val_loss: 0.0050 - val_acc: 1.0000
Epoch 70/100
162/163 [============================>.] - ETA: 0s - loss: 0.0000e+00 - ac
c: 1.0000Epoch 1/100
  1/163 [..............................] - ETA: 1:14 - loss: 0.0052 - acc:
1.0000
Epoch 00070: saving model to /content/data/model/weights.epoch_70.hdf5
163/163 [==============================] - 77s 475ms/step - loss: 0.0000e+
00 - acc: 1.0000 - val_loss: 0.0052 - val_acc: 1.0000
Epoch 71/100
162/163 [============================>.] - ETA: 0s - loss: 0.0000e+00 - ac
c: 1.0000Epoch 1/100
  1/163 [..............................] - ETA: 1:14 - loss: 0.0049 - acc:
1.0000
Epoch 00071: saving model to /content/data/model/weights.epoch_71.hdf5
163/163 [==============================] - 77s 469ms/step - loss: 0.0000e+
00 - acc: 1.0000 - val_loss: 0.0049 - val_acc: 1.0000
Epoch 72/100
162/163 [============================>.] - ETA: 0s - loss: 0.0000e+00 - ac
c: 1.0000Epoch 1/100
  1/163 [..............................] - ETA: 1:15 - loss: 0.0048 - acc:
1.0000
Epoch 00072: saving model to /content/data/model/weights.epoch_72.hdf5
163/163 [==============================] - 77s 473ms/step - loss: 0.0000e+
00 - acc: 1.0000 - val_loss: 0.0048 - val_acc: 1.0000
Epoch 73/100
162/163 [============================>.] - ETA: 0s - loss: 0.0000e+00 - ac
c: 1.0000Epoch 1/100
  1/163 [..............................] - ETA: 1:15 - loss: 0.0049 - acc:
1.0000
Epoch 00073: saving model to /content/data/model/weights.epoch_73.hdf5
163/163 [==============================] - 76s 467ms/step - loss: 0.0000e+
00 - acc: 1.0000 - val_loss: 0.0049 - val_acc: 1.0000
Epoch 74/100
162/163 [============================>.] - ETA: 0s - loss: 0.0000e+00 - ac
c: 1.0000Epoch 1/100
  1/163 [..............................] - ETA: 1:16 - loss: 0.0050 - acc:
1.0000
Epoch 00074: saving model to /content/data/model/weights.epoch_74.hdf5
163/163 [==============================] - 77s 471ms/step - loss: 0.0000e+
00 - acc: 1.0000 - val_loss: 0.0050 - val_acc: 1.0000
Epoch 75/100
162/163 [============================>.] - ETA: 0s - loss: 0.0000e+00 - ac
c: 1.0000Epoch 1/100
  1/163 [..............................] - ETA: 1:16 - loss: 0.0053 - acc:
1.0000
Epoch 00075: saving model to /content/data/model/weights.epoch_75.hdf5
163/163 [==============================] - 78s 480ms/step - loss: 0.0000e+
00 - acc: 1.0000 - val_loss: 0.0053 - val_acc: 1.0000
Epoch 76/100
162/163 [============================>.] - ETA: 0s - loss: 0.0000e+00 - ac
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c: 1.0000Epoch 1/100
  1/163 [..............................] - ETA: 1:17 - loss: 0.0052 - acc: 
1.0000
Epoch 00076: saving model to /content/data/model/weights.epoch_76.hdf5
163/163 [==============================] - 78s 479ms/step - loss: 0.0000e+
00 - acc: 1.0000 - val_loss: 0.0052 - val_acc: 1.0000
Epoch 77/100
162/163 [============================>.] - ETA: 0s - loss: 0.0000e+00 - ac
c: 1.0000Epoch 1/100
  1/163 [..............................] - ETA: 1:13 - loss: 0.0049 - acc: 
1.0000
Epoch 00077: saving model to /content/data/model/weights.epoch_77.hdf5
163/163 [==============================] - 76s 464ms/step - loss: 0.0000e+
00 - acc: 1.0000 - val_loss: 0.0049 - val_acc: 1.0000
Epoch 78/100
162/163 [============================>.] - ETA: 0s - loss: 0.0000e+00 - ac
c: 1.0000Epoch 1/100
  1/163 [..............................] - ETA: 1:15 - loss: 0.0047 - acc: 
1.0000
Epoch 00078: saving model to /content/data/model/weights.epoch_78.hdf5
163/163 [==============================] - 78s 476ms/step - loss: 0.0000e+
00 - acc: 1.0000 - val_loss: 0.0047 - val_acc: 1.0000
Epoch 79/100
162/163 [============================>.] - ETA: 0s - loss: 0.0000e+00 - ac
c: 1.0000Epoch 1/100
  1/163 [..............................] - ETA: 1:14 - loss: 0.0051 - acc: 
1.0000
Epoch 00079: saving model to /content/data/model/weights.epoch_79.hdf5
163/163 [==============================] - 78s 476ms/step - loss: 0.0000e+
00 - acc: 1.0000 - val_loss: 0.0051 - val_acc: 1.0000
Epoch 80/100
162/163 [============================>.] - ETA: 0s - loss: 0.0000e+00 - ac
c: 1.0000Epoch 1/100
  1/163 [..............................] - ETA: 1:16 - loss: 0.0049 - acc: 
1.0000
Epoch 00080: saving model to /content/data/model/weights.epoch_80.hdf5
163/163 [==============================] - 77s 472ms/step - loss: 0.0000e+
00 - acc: 1.0000 - val_loss: 0.0049 - val_acc: 1.0000
Epoch 81/100
162/163 [============================>.] - ETA: 0s - loss: 0.0000e+00 - ac
c: 1.0000Epoch 1/100
  1/163 [..............................] - ETA: 1:14 - loss: 0.0050 - acc: 
1.0000
Epoch 00081: saving model to /content/data/model/weights.epoch_81.hdf5
163/163 [==============================] - 76s 468ms/step - loss: 0.0000e+
00 - acc: 1.0000 - val_loss: 0.0050 - val_acc: 1.0000
Epoch 82/100
162/163 [============================>.] - ETA: 0s - loss: 0.0000e+00 - ac
c: 1.0000Epoch 1/100
  1/163 [..............................] - ETA: 1:16 - loss: 0.0049 - acc: 
1.0000
Epoch 00082: saving model to /content/data/model/weights.epoch_82.hdf5
163/163 [==============================] - 77s 471ms/step - loss: 0.0000e+
00 - acc: 1.0000 - val_loss: 0.0049 - val_acc: 1.0000
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Epoch 83/100
162/163 [============================>.] - ETA: 0s - loss: 0.0000e+00 - ac
c: 1.0000Epoch 1/100
  1/163 [..............................] - ETA: 1:16 - loss: 0.0053 - acc:
1.0000
Epoch 00083: saving model to /content/data/model/weights.epoch_83.hdf5
163/163 [==============================] - 78s 476ms/step - loss: 0.0000e+
00 - acc: 1.0000 - val_loss: 0.0053 - val_acc: 1.0000
Epoch 84/100
162/163 [============================>.] - ETA: 0s - loss: 0.0000e+00 - ac
c: 1.0000Epoch 1/100
  1/163 [..............................] - ETA: 1:14 - loss: 0.0052 - acc:
1.0000
Epoch 00084: saving model to /content/data/model/weights.epoch_84.hdf5
163/163 [==============================] - 77s 470ms/step - loss: 0.0000e+
00 - acc: 1.0000 - val_loss: 0.0052 - val_acc: 1.0000
Epoch 85/100
162/163 [============================>.] - ETA: 0s - loss: 0.0000e+00 - ac
c: 1.0000Epoch 1/100
  1/163 [..............................] - ETA: 1:14 - loss: 0.0047 - acc:
1.0000
Epoch 00085: saving model to /content/data/model/weights.epoch_85.hdf5
163/163 [==============================] - 76s 467ms/step - loss: 0.0000e+
00 - acc: 1.0000 - val_loss: 0.0047 - val_acc: 1.0000
Epoch 86/100
162/163 [============================>.] - ETA: 0s - loss: 0.0000e+00 - ac
c: 1.0000Epoch 1/100
  1/163 [..............................] - ETA: 1:17 - loss: 0.0052 - acc:
1.0000
Epoch 00086: saving model to /content/data/model/weights.epoch_86.hdf5
163/163 [==============================] - 77s 472ms/step - loss: 0.0000e+
00 - acc: 1.0000 - val_loss: 0.0052 - val_acc: 1.0000
Epoch 87/100
162/163 [============================>.] - ETA: 0s - loss: 0.0000e+00 - ac
c: 1.0000Epoch 1/100
  1/163 [..............................] - ETA: 1:15 - loss: 0.0051 - acc:
1.0000
Epoch 00087: saving model to /content/data/model/weights.epoch_87.hdf5
163/163 [==============================] - 78s 478ms/step - loss: 0.0000e+
00 - acc: 1.0000 - val_loss: 0.0051 - val_acc: 1.0000
Epoch 88/100
162/163 [============================>.] - ETA: 0s - loss: 0.0000e+00 - ac
c: 1.0000Epoch 1/100
  1/163 [..............................] - ETA: 1:16 - loss: 0.0052 - acc:
1.0000
Epoch 00088: saving model to /content/data/model/weights.epoch_88.hdf5
163/163 [==============================] - 78s 479ms/step - loss: 0.0000e+
00 - acc: 1.0000 - val_loss: 0.0052 - val_acc: 1.0000
Epoch 89/100
162/163 [============================>.] - ETA: 0s - loss: 0.0000e+00 - ac
c: 1.0000Epoch 1/100
  1/163 [..............................] - ETA: 1:16 - loss: 0.0055 - acc:
1.0000
Epoch 00089: saving model to /content/data/model/weights.epoch_89.hdf5
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163/163 [==============================] - 76s 469ms/step - loss: 0.0000e+
00 - acc: 1.0000 - val_loss: 0.0055 - val_acc: 1.0000
Epoch 90/100
162/163 [============================>.] - ETA: 0s - loss: 0.0000e+00 - ac
c: 1.0000Epoch 1/100
  1/163 [..............................] - ETA: 1:14 - loss: 0.0049 - acc:
1.0000
Epoch 00090: saving model to /content/data/model/weights.epoch_90.hdf5
163/163 [==============================] - 75s 463ms/step - loss: 0.0000e+
00 - acc: 1.0000 - val_loss: 0.0049 - val_acc: 1.0000
Epoch 91/100
162/163 [============================>.] - ETA: 0s - loss: 0.0000e+00 - ac
c: 1.0000Epoch 1/100
  1/163 [..............................] - ETA: 1:18 - loss: 0.0050 - acc:
1.0000
Epoch 00091: saving model to /content/data/model/weights.epoch_91.hdf5
163/163 [==============================] - 77s 473ms/step - loss: 0.0000e+
00 - acc: 1.0000 - val_loss: 0.0050 - val_acc: 1.0000
Epoch 92/100
162/163 [============================>.] - ETA: 0s - loss: 0.0000e+00 - ac
c: 1.0000Epoch 1/100
  1/163 [..............................] - ETA: 1:14 - loss: 0.0049 - acc:
1.0000
Epoch 00092: saving model to /content/data/model/weights.epoch_92.hdf5
163/163 [==============================] - 78s 476ms/step - loss: 0.0000e+
00 - acc: 1.0000 - val_loss: 0.0049 - val_acc: 1.0000
Epoch 93/100
162/163 [============================>.] - ETA: 0s - loss: 0.0000e+00 - ac
c: 1.0000Epoch 1/100
  1/163 [..............................] - ETA: 1:14 - loss: 0.0052 - acc:
1.0000
Epoch 00093: saving model to /content/data/model/weights.epoch_93.hdf5
163/163 [==============================] - 78s 476ms/step - loss: 0.0000e+
00 - acc: 1.0000 - val_loss: 0.0052 - val_acc: 1.0000
Epoch 94/100
162/163 [============================>.] - ETA: 0s - loss: 0.0000e+00 - ac
c: 1.0000Epoch 1/100
  1/163 [..............................] - ETA: 1:14 - loss: 0.0053 - acc:
1.0000
Epoch 00094: saving model to /content/data/model/weights.epoch_94.hdf5
163/163 [==============================] - 77s 474ms/step - loss: 0.0000e+
00 - acc: 1.0000 - val_loss: 0.0053 - val_acc: 1.0000
Epoch 95/100
162/163 [============================>.] - ETA: 0s - loss: 0.0000e+00 - ac
c: 1.0000Epoch 1/100
  1/163 [..............................] - ETA: 1:15 - loss: 0.0054 - acc:
1.0000
Epoch 00095: saving model to /content/data/model/weights.epoch_95.hdf5
163/163 [==============================] - 78s 477ms/step - loss: 0.0000e+
00 - acc: 1.0000 - val_loss: 0.0054 - val_acc: 1.0000
Epoch 96/100
162/163 [============================>.] - ETA: 0s - loss: 0.0000e+00 - ac
c: 1.0000Epoch 1/100
  1/163 [..............................] - ETA: 1:16 - loss: 0.0050 - acc:
```

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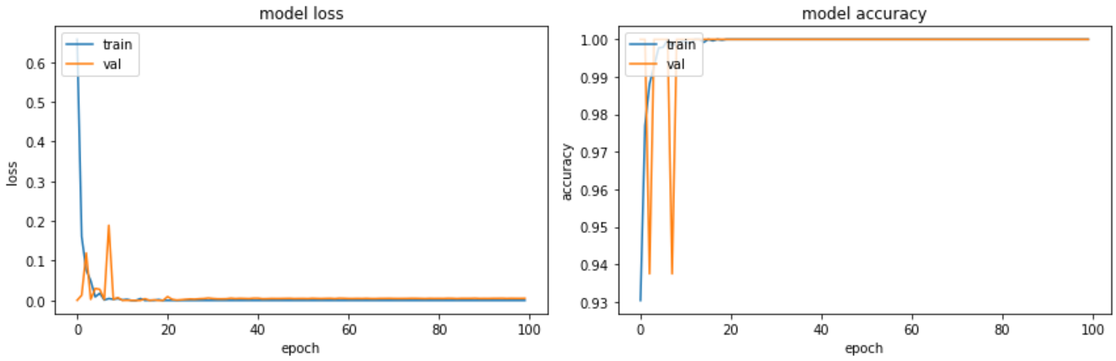
1.0000
Epoch 00096: saving model to /content/data/model/weights.epoch_96.hdf5
163/163 [==============================] - 78s 480ms/step - loss: 0.0000e+
00 - acc: 1.0000 - val_loss: 0.0050 - val_acc: 1.0000
Epoch 97/100
162/163 [============================>.] - ETA: 0s - loss: 0.0000e+00 - ac
c: 1.0000Epoch 1/100
  1/163 [..............................] - ETA: 1:14 - loss: 0.0053 - acc:
1.0000
Epoch 00097: saving model to /content/data/model/weights.epoch_97.hdf5
163/163 [==============================] - 78s 480ms/step - loss: 0.0000e+
00 - acc: 1.0000 - val_loss: 0.0053 - val_acc: 1.0000
Epoch 98/100
162/163 [============================>.] - ETA: 0s - loss: 0.0000e+00 - ac
c: 1.0000Epoch 1/100
  1/163 [..............................] - ETA: 1:17 - loss: 0.0051 - acc:
1.0000
Epoch 00098: saving model to /content/data/model/weights.epoch_98.hdf5
163/163 [==============================] - 78s 478ms/step - loss: 0.0000e+
00 - acc: 1.0000 - val_loss: 0.0051 - val_acc: 1.0000
Epoch 99/100
162/163 [============================>.] - ETA: 0s - loss: 0.0000e+00 - ac
c: 1.0000Epoch 1/100
  1/163 [..............................] - ETA: 1:13 - loss: 0.0051 - acc:
1.0000
Epoch 00099: saving model to /content/data/model/weights.epoch_99.hdf5
163/163 [==============================] - 77s 473ms/step - loss: 0.0000e+
00 - acc: 1.0000 - val_loss: 0.0051 - val_acc: 1.0000
Epoch 100/100
162/163 [============================>.] - ETA: 0s - loss: 0.0000e+00 - ac
c: 1.0000Epoch 1/100
  1/163 [..............................] - ETA: 1:15 - loss: 0.0053 - acc:
1.0000
Epoch 00100: saving model to /content/data/model/weights.epoch_100.hdf5
163/163 [==============================] - 76s 464ms/step - loss: 0.0000e+
00 - acc: 1.0000 - val_loss: 0.0053 - val_acc: 1.0000
Loading the best model
epoch: 14, val_loss: 6.705518984517767e-08, val_acc: 1.0
20/20 [==============================] - 10s 480ms/step - loss: 4.3357 - a
cc: 0.8157
20/20 [==============================] - 10s 494ms/step
CONFUSION MATRIX ------------------
[[120 114]
 [  1 389]]

TEST METRICS ----------------------
Accuracy: 81.57051282051282%
Precision: 77.33598409542743%
Recall: 99.74358974358975%
F1-score: 87.12206047032474

TRAIN METRIC ----------------------
Train acc: 100.0%
```


model loss
train
val
loss
epoch
model accuracy
train
val
accuracy
epoch

png

9.3 Appendix C: VGG16 Model 1 Version 1.1.0.0.0

```
from __future__ import absolute_import, division, print_function, unicode_
literals
import tensorflow as tf

# Extract dataset
import os
import tarfile

import keras_preprocessing
from keras_preprocessing.image import ImageDataGenerator # Data preprocess
ing and augmentation

import sklearn
import numpy as np
```

The default version of TensorFlow in Colab will soon switch to TensorFlow 2.x. We recommend you upgrade now or ensure your notebook will continue to use TensorFlow 1.x via the %tensorflow_version 1.x magic: more info.

```
print(tf.__version__)
```

```
1.15.0
```

```
# Make folder for chest xray data
!mkdir /content/data/

# Make directory to save weights
!mkdir /content/data/model

# Make directory to logs for Tensorboard
!mkdir /content/data/graph

# Download dataset
!wget --no-check-certificate \
    https://s3.eu-central-1.amazonaws.com/public.unit8.co/data/chest_xray.
tar.gz \
    -O /content/data/chest_xray.tar.gz

tar = tarfile.open("data/chest_xray.tar.gz")
tar.extractall(path='./data/')
os.remove('data/chest_xray.tar.gz')
```

```
--2019-10-31 04:30:59--  https://s3.eu-central-1.amazonaws.com/public.unit
8.co/data/chest_xray.tar.gz
Resolving s3.eu-central-1.amazonaws.com (s3.eu-central-1.amazonaws.com)...
52.219.74.151
Connecting to s3.eu-central-1.amazonaws.com (s3.eu-central-1.amazonaws.com
)|52.219.74.151|:443... connected.
HTTP request sent, awaiting response... 200 OK
Length: 1225393795 (1.1G) [application/x-gzip]
Saving to: ‘/content/data/chest_xray.tar.gz’
```

```
/content/data/chest 100%[==================>]   1.14G  30.0MB/s    in 40s

2019-10-31 04:31:39 (29.2 MB/s) - ‘/content/data/chest_xray.tar.gz’ saved
[1225393795/1225393795]
```

Change log: > training_datagen –> ImageDataGenerator

trainable layer –> All except base

20 layers VGG16 model - base, flat, dense

Optimizer = RMSprop(learning_rate = 0.001)

loss = categorical_crosscentropy

callback = [checkpoints]

epochs = 100

no class weight balancing

```
TRAINING_DIR = "/content/data/chest_xray/train"
VALIDATION_DIR = "/content/data/chest_xray/val"
TEST_DIR = "/content/data/chest_xray/test"
```

```
# Data preprocessing
training_datagen = ImageDataGenerator(
    preprocessing_function=tf.keras.applications.vgg16.preprocess_input,
    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,
    # vertical_flip=True
    fill_mode='nearest'
)

validation_datagen = ImageDataGenerator(
    rescale = 1./255
)

test_datagen = ImageDataGenerator(
    rescale = 1./255
)

# Create training data batch
train_generator = training_datagen.flow_from_directory(
    TRAINING_DIR,
    target_size=(150,150),
    class_mode='categorical'
)
```

```
validation_generator = validation_datagen.flow_from_directory(
    VALIDATION_DIR,
    target_size=(150,150),
    class_mode='categorical'
)

test_generator = test_datagen.flow_from_directory(
    TEST_DIR,
    target_size=(150,150),
    class_mode='categorical',
    shuffle=False
)

train_shape = train_generator.image_shape

tf.keras.backend.clear_session() # Destroys the current TF graph and creat
es a new one.

base_model = tf.keras.applications.VGG16(weights='imagenet', include_top=F
alse, input_shape=train_shape)

# Define the machine learning model
x = base_model.output
x = tf.keras.layers.Flatten()(x)
x = tf.keras.layers.Dense(2, 'softmax')(x)

model = tf.keras.Model(inputs=base_model.input, outputs=x)

# for layer in model.layers[0:20]:
#     layer.trainable = False

for layer in base_model.layers:
  layer.trainable = False

optimizer = tf.keras.optimizers.RMSprop(learning_rate=0.001)

model.compile(loss='categorical_crossentropy',
              optimizer=optimizer,
              metrics=['accuracy'])

# Callbacks stuff
# Function to save the weights of the model after each epoch
checkpoint = tf.keras.callbacks.ModelCheckpoint(
    '/content/data/model/weights.epoch_{epoch:02d}.hdf5',
    monitor='val_accuracy',
    save_best_only=False,
    save_weights_only=False,
    mode='auto',
    verbose=1
)

# Function to stop training early if there's no improvement
early_stopping_monitor = tf.keras.callbacks.EarlyStopping(patience = 3, mo
nitor = "val_loss", mode="auto", verbose = 1)
```

```
lr_reduce = tf.keras.callbacks.ReduceLROnPlateau(monitor='val_loss', facto
r=0.3, patience=2, verbose=1, mode='max')

classweight = sklearn.utils.class_weight.compute_class_weight('balanced',
np.unique(train_generator.labels), train_generator.labels)
print(classweight)

batch_size = 32
epochs = 100

# Training process
history = model.fit_generator(
    generator=train_generator,
    # steps_per_epoch=train_generator.samples//batch_size,
    epochs=epochs,
    # callbacks=[early_stopping_monitor],
    callbacks=[checkpoint],
    # shuffle=True,
    validation_data=validation_generator,
    # validation_steps= validation_generator//batch_size, #no because it's
gonna be 0... if leave alone its len(generator) which is equal to 1.
    # class_weight=classweight,
    verbose = 1
)

## Graph loss and acc
import matplotlib.pyplot as plt
def plot_learning_curves(history):
    plt.figure(figsize=(12,4))

    plt.subplot(1,2,1)
    plt.plot(history.history['loss'])
    plt.plot(history.history['val_loss'])
    plt.title('model loss')
    plt.ylabel('loss')
    plt.xlabel('epoch')
    plt.legend(['train', 'val'], loc='upper left')

    plt.subplot(1,2,2)
    plt.plot(history.history['acc'])
    plt.plot(history.history['val_acc'])
    plt.title('model accuracy')
    plt.ylabel('accuracy')
    plt.xlabel('epoch')
    plt.legend(['train', 'val'], loc='upper left')

    plt.tight_layout()

plot_learning_curves(history)


## Evaualate
test_loss, test_acc = model.evaluate_generator(generator=test_generator, v
```

```
erbose=1)

## Load best weight
idx = np.argmin(history.history['val_loss'])
model.load_weights("/content/data/model/weights.epoch_{:02d}.hdf5".format(
idx + 1))

print("Loading the best model")
print("epoch: {}, val_loss: {}, val_acc: {}".format(idx + 1, history.histo
ry['val_loss'][idx], history.history['val_acc'][idx]))

## Evaluate the best weight
test_loss, test_acc = model.evaluate_generator(generator=test_generator, v
erbose=1)

## Test analytics
from sklearn.metrics import accuracy_score, confusion_matrix

test_generator.reset()
test_preds = model.predict_generator(test_generator, verbose=1)
test_preds = np.argmax(test_preds,axis=1)

acc = accuracy_score(test_generator.classes, test_preds)*100
cm = confusion_matrix(test_generator.classes, test_preds)
tn, fp, fn, tp = cm.ravel()

print('CONFUSION MATRIX ------------------')
print(cm)
# plot_confusion_matrix(cm, target_names=['NORMAL', 'PNEUMONIA'], normaliz
e=False)


print('\nTEST METRICS ----------------------')
precision = tp/(tp+fp)*100
recall = tp/(tp+fn)*100
print('Accuracy: {}%'.format(acc))
print('Precision: {}%'.format(precision))
print('Recall: {}%'.format(recall))
print('F1-score: {}'.format(2*precision*recall/(precision+recall)))

print('\nTRAIN METRIC ----------------------')
print('Train acc: {}%'.format(np.round((history.history['acc'][-1])*100, 1
4)))
```

```
Found 5216 images belonging to 2 classes.
Found 16 images belonging to 2 classes.
Found 624 images belonging to 2 classes.
[1.9448173  0.67303226]
Epoch 1/100
162/163 [============================>.] - ETA: 0s - loss: 0.2429 - acc: 0
.8978Epoch 1/100
  1/163 [..............................] - ETA: 4:07 - loss: 0.5661 - acc:
0.7500
Epoch 00001: saving model to /content/data/model/weights.epoch_01.hdf5
```

```
163/163 [==============================] - 89s 547ms/step - loss: 0.2419 -
acc: 0.8980 - val_loss: 0.5661 - val_acc: 0.7500
Epoch 2/100
162/163 [============================>.] - ETA: 0s - loss: 0.1500 - acc: 0
.9417Epoch 1/100
  1/163 [..............................] - ETA: 56s - loss: 0.2780 - acc:
0.8125
Epoch 00002: saving model to /content/data/model/weights.epoch_02.hdf5
163/163 [==============================] - 88s 537ms/step - loss: 0.1495 -
acc: 0.9419 - val_loss: 0.2780 - val_acc: 0.8125
Epoch 3/100
162/163 [============================>.] - ETA: 0s - loss: 0.1334 - acc: 0
.9466Epoch 1/100
  1/163 [..............................] - ETA: 54s - loss: 0.8554 - acc:
0.7500
Epoch 00003: saving model to /content/data/model/weights.epoch_03.hdf5
163/163 [==============================] - 87s 537ms/step - loss: 0.1343 -
acc: 0.9465 - val_loss: 0.8554 - val_acc: 0.7500
Epoch 4/100
162/163 [============================>.] - ETA: 0s - loss: 0.1295 - acc: 0
.9508Epoch 1/100
  1/163 [..............................] - ETA: 58s - loss: 0.4039 - acc:
0.8750
Epoch 00004: saving model to /content/data/model/weights.epoch_04.hdf5
163/163 [==============================] - 87s 534ms/step - loss: 0.1301 -
acc: 0.9505 - val_loss: 0.4039 - val_acc: 0.8750
Epoch 5/100
162/163 [============================>.] - ETA: 0s - loss: 0.1242 - acc: 0
.9564Epoch 1/100
  1/163 [..............................] - ETA: 53s - loss: 0.4727 - acc:
0.8125
Epoch 00005: saving model to /content/data/model/weights.epoch_05.hdf5
163/163 [==============================] - 86s 530ms/step - loss: 0.1237 -
acc: 0.9567 - val_loss: 0.4727 - val_acc: 0.8125
Epoch 6/100
162/163 [============================>.] - ETA: 0s - loss: 0.1231 - acc: 0
.9574Epoch 1/100
  1/163 [..............................] - ETA: 56s - loss: 0.2148 - acc:
0.8750
Epoch 00006: saving model to /content/data/model/weights.epoch_06.hdf5
163/163 [==============================] - 87s 533ms/step - loss: 0.1231 -
acc: 0.9572 - val_loss: 0.2148 - val_acc: 0.8750
Epoch 7/100
162/163 [============================>.] - ETA: 0s - loss: 0.1223 - acc: 0
.9535Epoch 1/100
  1/163 [..............................] - ETA: 55s - loss: 0.1770 - acc:
0.9375
Epoch 00007: saving model to /content/data/model/weights.epoch_07.hdf5
163/163 [==============================] - 87s 536ms/step - loss: 0.1216 -
acc: 0.9538 - val_loss: 0.1770 - val_acc: 0.9375
Epoch 8/100
162/163 [============================>.] - ETA: 0s - loss: 0.1123 - acc: 0
.9576Epoch 1/100
  1/163 [..............................] - ETA: 53s - loss: 0.1544 - acc:
```

```
0.9375
Epoch 00008: saving model to /content/data/model/weights.epoch_08.hdf5
163/163 [==============================] - 86s 527ms/step - loss: 0.1119 -
acc: 0.9576 - val_loss: 0.1544 - val_acc: 0.9375
Epoch 9/100
162/163 [============================>.] - ETA: 0s - loss: 0.1011 - acc: 0
.9585Epoch 1/100
  1/163 [..............................] - ETA: 53s - loss: 0.1367 - acc:
0.9375
Epoch 00009: saving model to /content/data/model/weights.epoch_09.hdf5
163/163 [==============================] - 87s 535ms/step - loss: 0.1007 -
acc: 0.9588 - val_loss: 0.1367 - val_acc: 0.9375
Epoch 10/100
162/163 [============================>.] - ETA: 0s - loss: 0.0992 - acc: 0
.9626Epoch 1/100
  1/163 [..............................] - ETA: 54s - loss: 0.1243 - acc:
0.9375
Epoch 00010: saving model to /content/data/model/weights.epoch_10.hdf5
163/163 [==============================] - 87s 533ms/step - loss: 0.1000 -
acc: 0.9624 - val_loss: 0.1243 - val_acc: 0.9375
Epoch 11/100
162/163 [============================>.] - ETA: 0s - loss: 0.1025 - acc: 0
.9616Epoch 1/100
  1/163 [..............................] - ETA: 56s - loss: 0.1493 - acc:
0.9375
Epoch 00011: saving model to /content/data/model/weights.epoch_11.hdf5
163/163 [==============================] - 87s 534ms/step - loss: 0.1022 -
acc: 0.9617 - val_loss: 0.1493 - val_acc: 0.9375
Epoch 12/100
162/163 [============================>.] - ETA: 0s - loss: 0.0990 - acc: 0
.9601Epoch 1/100
  1/163 [..............................] - ETA: 54s - loss: 0.1211 - acc:
0.8750
Epoch 00012: saving model to /content/data/model/weights.epoch_12.hdf5
163/163 [==============================] - 87s 535ms/step - loss: 0.0993 -
acc: 0.9601 - val_loss: 0.1211 - val_acc: 0.8750
Epoch 13/100
162/163 [============================>.] - ETA: 0s - loss: 0.0991 - acc: 0
.9612Epoch 1/100
  1/163 [..............................] - ETA: 54s - loss: 0.1547 - acc:
0.9375
Epoch 00013: saving model to /content/data/model/weights.epoch_13.hdf5
163/163 [==============================] - 87s 535ms/step - loss: 0.0995 -
acc: 0.9613 - val_loss: 0.1547 - val_acc: 0.9375
Epoch 14/100
162/163 [============================>.] - ETA: 0s - loss: 0.0935 - acc: 0
.9651Epoch 1/100
  1/163 [..............................] - ETA: 56s - loss: 0.1807 - acc:
0.9375
Epoch 00014: saving model to /content/data/model/weights.epoch_14.hdf5
163/163 [==============================] - 86s 530ms/step - loss: 0.0935 -
acc: 0.9651 - val_loss: 0.1807 - val_acc: 0.9375
Epoch 15/100
162/163 [============================>.] - ETA: 0s - loss: 0.0903 - acc: 0
```

```
.9637Epoch 1/100
  1/163 [..............................] - ETA: 55s - loss: 0.1229 - acc:
0.9375
Epoch 00015: saving model to /content/data/model/weights.epoch_15.hdf5
163/163 [==============================] - 87s 531ms/step - loss: 0.0902 -
acc: 0.9636 - val_loss: 0.1229 - val_acc: 0.9375
Epoch 16/100
162/163 [============================>.] - ETA: 0s - loss: 0.0904 - acc: 0
.9664Epoch 1/100
  1/163 [..............................] - ETA: 59s - loss: 0.1215 - acc:
0.9375
Epoch 00016: saving model to /content/data/model/weights.epoch_16.hdf5
163/163 [==============================] - 87s 532ms/step - loss: 0.0899 -
acc: 0.9666 - val_loss: 0.1215 - val_acc: 0.9375
Epoch 17/100
162/163 [============================>.] - ETA: 0s - loss: 0.0922 - acc: 0
.9637Epoch 1/100
  1/163 [..............................] - ETA: 56s - loss: 0.3688 - acc:
0.8125
Epoch 00017: saving model to /content/data/model/weights.epoch_17.hdf5
163/163 [==============================] - 87s 532ms/step - loss: 0.0922 -
acc: 0.9636 - val_loss: 0.3688 - val_acc: 0.8125
Epoch 18/100
162/163 [============================>.] - ETA: 0s - loss: 0.0894 - acc: 0
.9682Epoch 1/100
  1/163 [..............................] - ETA: 55s - loss: 0.1606 - acc:
0.9375
Epoch 00018: saving model to /content/data/model/weights.epoch_18.hdf5
163/163 [==============================] - 85s 524ms/step - loss: 0.0890 -
acc: 0.9684 - val_loss: 0.1606 - val_acc: 0.9375
Epoch 19/100
162/163 [============================>.] - ETA: 0s - loss: 0.0851 - acc: 0
.9695Epoch 1/100
  1/163 [..............................] - ETA: 56s - loss: 0.1894 - acc:
0.8750
Epoch 00019: saving model to /content/data/model/weights.epoch_19.hdf5
163/163 [==============================] - 87s 533ms/step - loss: 0.0850 -
acc: 0.9695 - val_loss: 0.1894 - val_acc: 0.8750
Epoch 20/100
162/163 [============================>.] - ETA: 0s - loss: 0.0860 - acc: 0
.9688Epoch 1/100
  1/163 [..............................] - ETA: 56s - loss: 0.2548 - acc:
0.8750
Epoch 00020: saving model to /content/data/model/weights.epoch_20.hdf5
163/163 [==============================] - 86s 529ms/step - loss: 0.0860 -
acc: 0.9686 - val_loss: 0.2548 - val_acc: 0.8750
Epoch 21/100
162/163 [============================>.] - ETA: 0s - loss: 0.0882 - acc: 0
.9662Epoch 1/100
  1/163 [..............................] - ETA: 57s - loss: 0.3508 - acc:
0.7500
Epoch 00021: saving model to /content/data/model/weights.epoch_21.hdf5
163/163 [==============================] - 87s 532ms/step - loss: 0.0877 -
acc: 0.9664 - val_loss: 0.3508 - val_acc: 0.7500
```

```
Epoch 22/100
162/163 [============================>.] - ETA: 0s - loss: 0.0787 - acc: 0
.9709Epoch 1/100
  1/163 [..............................] - ETA: 58s - loss: 0.1240 - acc:
0.9375
Epoch 00022: saving model to /content/data/model/weights.epoch_22.hdf5
163/163 [==============================] - 86s 529ms/step - loss: 0.0788 -
acc: 0.9709 - val_loss: 0.1240 - val_acc: 0.9375
Epoch 23/100
162/163 [============================>.] - ETA: 0s - loss: 0.0871 - acc: 0
.9682Epoch 1/100
  1/163 [..............................] - ETA: 57s - loss: 0.1897 - acc:
0.9375
Epoch 00023: saving model to /content/data/model/weights.epoch_23.hdf5
163/163 [==============================] - 87s 533ms/step - loss: 0.0867 -
acc: 0.9684 - val_loss: 0.1897 - val_acc: 0.9375
Epoch 24/100
162/163 [============================>.] - ETA: 0s - loss: 0.0806 - acc: 0
.9720Epoch 1/100
  1/163 [..............................] - ETA: 59s - loss: 0.1861 - acc:
0.9375
Epoch 00024: saving model to /content/data/model/weights.epoch_24.hdf5
163/163 [==============================] - 87s 535ms/step - loss: 0.0806 -
acc: 0.9718 - val_loss: 0.1861 - val_acc: 0.9375
Epoch 25/100
162/163 [============================>.] - ETA: 0s - loss: 0.0777 - acc: 0
.9709Epoch 1/100
  1/163 [..............................] - ETA: 57s - loss: 0.0779 - acc:
0.9375
Epoch 00025: saving model to /content/data/model/weights.epoch_25.hdf5
163/163 [==============================] - 87s 536ms/step - loss: 0.0786 -
acc: 0.9707 - val_loss: 0.0779 - val_acc: 0.9375
Epoch 26/100
162/163 [============================>.] - ETA: 0s - loss: 0.0848 - acc: 0
.9674Epoch 1/100
  1/163 [..............................] - ETA: 56s - loss: 0.1038 - acc:
0.9375
Epoch 00026: saving model to /content/data/model/weights.epoch_26.hdf5
163/163 [==============================] - 87s 536ms/step - loss: 0.0855 -
acc: 0.9668 - val_loss: 0.1038 - val_acc: 0.9375
Epoch 27/100
162/163 [============================>.] - ETA: 0s - loss: 0.0792 - acc: 0
.9724Epoch 1/100
  1/163 [..............................] - ETA: 54s - loss: 0.1531 - acc:
0.8750
Epoch 00027: saving model to /content/data/model/weights.epoch_27.hdf5
163/163 [==============================] - 87s 535ms/step - loss: 0.0788 -
acc: 0.9726 - val_loss: 0.1531 - val_acc: 0.8750
Epoch 28/100
162/163 [============================>.] - ETA: 0s - loss: 0.0796 - acc: 0
.9703Epoch 1/100
  1/163 [..............................] - ETA: 53s - loss: 0.2089 - acc:
0.9375
Epoch 00028: saving model to /content/data/model/weights.epoch_28.hdf5
```

```
163/163 [==============================] - 87s 534ms/step - loss: 0.0806 -
acc: 0.9701 - val_loss: 0.2089 - val_acc: 0.9375
Epoch 29/100
162/163 [============================>.] - ETA: 0s - loss: 0.0831 - acc: 0
.9682Epoch 1/100
  1/163 [..............................] - ETA: 59s - loss: 0.0790 - acc:
1.0000
Epoch 00029: saving model to /content/data/model/weights.epoch_29.hdf5
163/163 [==============================] - 87s 533ms/step - loss: 0.0826 -
acc: 0.9684 - val_loss: 0.0790 - val_acc: 1.0000
Epoch 30/100
162/163 [============================>.] - ETA: 0s - loss: 0.0822 - acc: 0
.9701Epoch 1/100
  1/163 [..............................] - ETA: 55s - loss: 0.0625 - acc:
1.0000
Epoch 00030: saving model to /content/data/model/weights.epoch_30.hdf5
163/163 [==============================] - 87s 532ms/step - loss: 0.0818 -
acc: 0.9703 - val_loss: 0.0625 - val_acc: 1.0000
Epoch 31/100
162/163 [============================>.] - ETA: 0s - loss: 0.0761 - acc: 0
.9726Epoch 1/100
  1/163 [..............................] - ETA: 54s - loss: 0.1074 - acc:
1.0000
Epoch 00031: saving model to /content/data/model/weights.epoch_31.hdf5
163/163 [==============================] - 87s 537ms/step - loss: 0.0757 -
acc: 0.9728 - val_loss: 0.1074 - val_acc: 1.0000
Epoch 32/100
162/163 [============================>.] - ETA: 0s - loss: 0.0763 - acc: 0
.9703Epoch 1/100
  1/163 [..............................] - ETA: 57s - loss: 0.0581 - acc:
1.0000
Epoch 00032: saving model to /content/data/model/weights.epoch_32.hdf5
163/163 [==============================] - 88s 538ms/step - loss: 0.0763 -
acc: 0.9701 - val_loss: 0.0581 - val_acc: 1.0000
Epoch 33/100
162/163 [============================>.] - ETA: 0s - loss: 0.0768 - acc: 0
.9707Epoch 1/100
  1/163 [..............................] - ETA: 57s - loss: 0.1973 - acc:
0.8750
Epoch 00033: saving model to /content/data/model/weights.epoch_33.hdf5
163/163 [==============================] - 87s 536ms/step - loss: 0.0766 -
acc: 0.9707 - val_loss: 0.1973 - val_acc: 0.8750
Epoch 34/100
162/163 [============================>.] - ETA: 0s - loss: 0.0793 - acc: 0
.9722Epoch 1/100
  1/163 [..............................] - ETA: 55s - loss: 0.0914 - acc:
1.0000
Epoch 00034: saving model to /content/data/model/weights.epoch_34.hdf5
163/163 [==============================] - 87s 537ms/step - loss: 0.0792 -
acc: 0.9722 - val_loss: 0.0914 - val_acc: 1.0000
Epoch 35/100
162/163 [============================>.] - ETA: 0s - loss: 0.0749 - acc: 0
.9709Epoch 1/100
  1/163 [..............................] - ETA: 56s - loss: 0.1380 - acc:
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0.9375
Epoch 00035: saving model to /content/data/model/weights.epoch_35.hdf5
163/163 [==============================] - 87s 535ms/step - loss: 0.0749 -
acc: 0.9709 - val_loss: 0.1380 - val_acc: 0.9375
Epoch 36/100
162/163 [============================>.] - ETA: 0s - loss: 0.0703 - acc: 0
.9718Epoch 1/100
  1/163 [..............................] - ETA: 55s - loss: 0.1734 - acc:
0.8750
Epoch 00036: saving model to /content/data/model/weights.epoch_36.hdf5
163/163 [==============================] - 87s 537ms/step - loss: 0.0700 -
acc: 0.9720 - val_loss: 0.1734 - val_acc: 0.8750
Epoch 37/100
162/163 [============================>.] - ETA: 0s - loss: 0.0755 - acc: 0
.9715Epoch 1/100
  1/163 [..............................] - ETA: 54s - loss: 0.1433 - acc:
0.9375
Epoch 00037: saving model to /content/data/model/weights.epoch_37.hdf5
163/163 [==============================] - 88s 541ms/step - loss: 0.0757 -
acc: 0.9712 - val_loss: 0.1433 - val_acc: 0.9375
Epoch 38/100
162/163 [============================>.] - ETA: 0s - loss: 0.0751 - acc: 0
.9732Epoch 1/100
  1/163 [..............................] - ETA: 57s - loss: 0.1892 - acc:
0.9375
Epoch 00038: saving model to /content/data/model/weights.epoch_38.hdf5
163/163 [==============================] - 88s 537ms/step - loss: 0.0754 -
acc: 0.9732 - val_loss: 0.1892 - val_acc: 0.9375
Epoch 39/100
162/163 [============================>.] - ETA: 0s - loss: 0.0752 - acc: 0
.9722Epoch 1/100
  1/163 [..............................] - ETA: 58s - loss: 0.0646 - acc:
1.0000
Epoch 00039: saving model to /content/data/model/weights.epoch_39.hdf5
163/163 [==============================] - 87s 534ms/step - loss: 0.0748 -
acc: 0.9724 - val_loss: 0.0646 - val_acc: 1.0000
Epoch 40/100
162/163 [============================>.] - ETA: 0s - loss: 0.0698 - acc: 0
.9745Epoch 1/100
  1/163 [..............................] - ETA: 57s - loss: 0.4798 - acc:
0.7500
Epoch 00040: saving model to /content/data/model/weights.epoch_40.hdf5
163/163 [==============================] - 87s 535ms/step - loss: 0.0700 -
acc: 0.9745 - val_loss: 0.4798 - val_acc: 0.7500
Epoch 41/100
162/163 [============================>.] - ETA: 0s - loss: 0.0742 - acc: 0
.9718Epoch 1/100
  1/163 [..............................] - ETA: 58s - loss: 0.0673 - acc:
0.9375
Epoch 00041: saving model to /content/data/model/weights.epoch_41.hdf5
163/163 [==============================] - 87s 536ms/step - loss: 0.0738 -
acc: 0.9720 - val_loss: 0.0673 - val_acc: 0.9375
Epoch 42/100
162/163 [============================>.] - ETA: 0s - loss: 0.0669 - acc: 0
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.9730Epoch 1/100
  1/163 [..............................] - ETA: 59s - loss: 0.0433 - acc: 
1.0000
Epoch 00042: saving model to /content/data/model/weights.epoch_42.hdf5
163/163 [==============================] - 87s 536ms/step - loss: 0.0669 - 
acc: 0.9730 - val_loss: 0.0433 - val_acc: 1.0000
Epoch 43/100
162/163 [============================>.] - ETA: 0s - loss: 0.0704 - acc: 0
.9732Epoch 1/100
  1/163 [..............................] - ETA: 55s - loss: 0.0838 - acc: 
1.0000
Epoch 00043: saving model to /content/data/model/weights.epoch_43.hdf5
163/163 [==============================] - 88s 538ms/step - loss: 0.0701 - 
acc: 0.9734 - val_loss: 0.0838 - val_acc: 1.0000
Epoch 44/100
162/163 [============================>.] - ETA: 0s - loss: 0.0802 - acc: 0
.9699Epoch 1/100
  1/163 [..............................] - ETA: 55s - loss: 0.0449 - acc: 
1.0000
Epoch 00044: saving model to /content/data/model/weights.epoch_44.hdf5
163/163 [==============================] - 87s 534ms/step - loss: 0.0798 - 
acc: 0.9701 - val_loss: 0.0449 - val_acc: 1.0000
Epoch 45/100
162/163 [============================>.] - ETA: 0s - loss: 0.0697 - acc: 0
.9734Epoch 1/100
  1/163 [..............................] - ETA: 55s - loss: 0.0499 - acc: 
1.0000
Epoch 00045: saving model to /content/data/model/weights.epoch_45.hdf5
163/163 [==============================] - 87s 533ms/step - loss: 0.0695 - 
acc: 0.9735 - val_loss: 0.0499 - val_acc: 1.0000
Epoch 46/100
162/163 [============================>.] - ETA: 0s - loss: 0.0701 - acc: 0
.9720Epoch 1/100
  1/163 [..............................] - ETA: 56s - loss: 0.1592 - acc: 
0.8750
Epoch 00046: saving model to /content/data/model/weights.epoch_46.hdf5
163/163 [==============================] - 88s 541ms/step - loss: 0.0698 - 
acc: 0.9720 - val_loss: 0.1592 - val_acc: 0.8750
Epoch 47/100
162/163 [============================>.] - ETA: 0s - loss: 0.0718 - acc: 0
.9715Epoch 1/100
  1/163 [..............................] - ETA: 59s - loss: 0.0679 - acc: 
1.0000
Epoch 00047: saving model to /content/data/model/weights.epoch_47.hdf5
163/163 [==============================] - 89s 544ms/step - loss: 0.0714 - 
acc: 0.9716 - val_loss: 0.0679 - val_acc: 1.0000
Epoch 48/100
162/163 [============================>.] - ETA: 0s - loss: 0.0682 - acc: 0
.9728Epoch 1/100
  1/163 [..............................] - ETA: 55s - loss: 0.1295 - acc: 
0.8750
Epoch 00048: saving model to /content/data/model/weights.epoch_48.hdf5
163/163 [==============================] - 87s 531ms/step - loss: 0.0689 - 
acc: 0.9726 - val_loss: 0.1295 - val_acc: 0.8750
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Epoch 49/100
162/163 [============================>.] - ETA: 0s - loss: 0.0733 - acc: 0
.9726Epoch 1/100
  1/163 [..............................] - ETA: 56s - loss: 0.0895 - acc:
0.9375
Epoch 00049: saving model to /content/data/model/weights.epoch_49.hdf5
163/163 [==============================] - 87s 535ms/step - loss: 0.0731 -
acc: 0.9726 - val_loss: 0.0895 - val_acc: 0.9375
Epoch 50/100
162/163 [============================>.] - ETA: 0s - loss: 0.0686 - acc: 0
.9743Epoch 1/100
  1/163 [..............................] - ETA: 55s - loss: 0.1431 - acc:
0.9375
Epoch 00050: saving model to /content/data/model/weights.epoch_50.hdf5
163/163 [==============================] - 86s 531ms/step - loss: 0.0686 -
acc: 0.9743 - val_loss: 0.1431 - val_acc: 0.9375
Epoch 51/100
162/163 [============================>.] - ETA: 0s - loss: 0.0688 - acc: 0
.9734Epoch 1/100
  1/163 [..............................] - ETA: 57s - loss: 0.1358 - acc:
0.9375
Epoch 00051: saving model to /content/data/model/weights.epoch_51.hdf5
163/163 [==============================] - 86s 526ms/step - loss: 0.0687 -
acc: 0.9732 - val_loss: 0.1358 - val_acc: 0.9375
Epoch 52/100
162/163 [============================>.] - ETA: 0s - loss: 0.0702 - acc: 0
.9740Epoch 1/100
  1/163 [..............................] - ETA: 56s - loss: 0.2695 - acc:
0.8125
Epoch 00052: saving model to /content/data/model/weights.epoch_52.hdf5
163/163 [==============================] - 87s 536ms/step - loss: 0.0705 -
acc: 0.9737 - val_loss: 0.2695 - val_acc: 0.8125
Epoch 53/100
162/163 [============================>.] - ETA: 0s - loss: 0.0664 - acc: 0
.9751Epoch 1/100
  1/163 [..............................] - ETA: 56s - loss: 0.0418 - acc:
1.0000
Epoch 00053: saving model to /content/data/model/weights.epoch_53.hdf5
163/163 [==============================] - 87s 535ms/step - loss: 0.0661 -
acc: 0.9753 - val_loss: 0.0418 - val_acc: 1.0000
Epoch 54/100
162/163 [============================>.] - ETA: 0s - loss: 0.0659 - acc: 0
.9755Epoch 1/100
  1/163 [..............................] - ETA: 59s - loss: 0.0923 - acc:
0.9375
Epoch 00054: saving model to /content/data/model/weights.epoch_54.hdf5
163/163 [==============================] - 87s 536ms/step - loss: 0.0659 -
acc: 0.9755 - val_loss: 0.0923 - val_acc: 0.9375
Epoch 55/100
162/163 [============================>.] - ETA: 0s - loss: 0.0629 - acc: 0
.9778Epoch 1/100
  1/163 [..............................] - ETA: 56s - loss: 0.1823 - acc:
0.8750
Epoch 00055: saving model to /content/data/model/weights.epoch_55.hdf5
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163/163 [==============================] - 88s 540ms/step - loss: 0.0633 -
acc: 0.9778 - val_loss: 0.1823 - val_acc: 0.8750
Epoch 56/100
162/163 [============================>.] - ETA: 0s - loss: 0.0696 - acc: 0
.9738Epoch 1/100
  1/163 [..............................] - ETA: 55s - loss: 0.2149 - acc:
0.9375
Epoch 00056: saving model to /content/data/model/weights.epoch_56.hdf5
163/163 [==============================] - 88s 540ms/step - loss: 0.0699 -
acc: 0.9735 - val_loss: 0.2149 - val_acc: 0.9375
Epoch 57/100
162/163 [============================>.] - ETA: 0s - loss: 0.0674 - acc: 0
.9755Epoch 1/100
  1/163 [..............................] - ETA: 53s - loss: 0.0913 - acc:
1.0000
Epoch 00057: saving model to /content/data/model/weights.epoch_57.hdf5
163/163 [==============================] - 87s 536ms/step - loss: 0.0674 -
acc: 0.9755 - val_loss: 0.0913 - val_acc: 1.0000
Epoch 58/100
162/163 [============================>.] - ETA: 0s - loss: 0.0683 - acc: 0
.9765Epoch 1/100
  1/163 [..............................] - ETA: 57s - loss: 0.0494 - acc:
1.0000
Epoch 00058: saving model to /content/data/model/weights.epoch_58.hdf5
163/163 [==============================] - 88s 539ms/step - loss: 0.0694 -
acc: 0.9762 - val_loss: 0.0494 - val_acc: 1.0000
Epoch 59/100
162/163 [============================>.] - ETA: 0s - loss: 0.0671 - acc: 0
.9755Epoch 1/100
  1/163 [..............................] - ETA: 56s - loss: 0.0989 - acc:
1.0000
Epoch 00059: saving model to /content/data/model/weights.epoch_59.hdf5
163/163 [==============================] - 87s 536ms/step - loss: 0.0669 -
acc: 0.9757 - val_loss: 0.0989 - val_acc: 1.0000
Epoch 60/100
162/163 [============================>.] - ETA: 0s - loss: 0.0672 - acc: 0
.9738Epoch 1/100
  1/163 [..............................] - ETA: 54s - loss: 0.0486 - acc:
1.0000
Epoch 00060: saving model to /content/data/model/weights.epoch_60.hdf5
163/163 [==============================] - 86s 530ms/step - loss: 0.0669 -
acc: 0.9739 - val_loss: 0.0486 - val_acc: 1.0000
Epoch 61/100
162/163 [============================>.] - ETA: 0s - loss: 0.0659 - acc: 0
.9770Epoch 1/100
  1/163 [..............................] - ETA: 55s - loss: 0.0884 - acc:
1.0000
Epoch 00061: saving model to /content/data/model/weights.epoch_61.hdf5
163/163 [==============================] - 87s 534ms/step - loss: 0.0656 -
acc: 0.9772 - val_loss: 0.0884 - val_acc: 1.0000
Epoch 62/100
162/163 [============================>.] - ETA: 0s - loss: 0.0616 - acc: 0
.9753Epoch 1/100
  1/163 [..............................] - ETA: 55s - loss: 0.0403 - acc:
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1.0000
Epoch 00062: saving model to /content/data/model/weights.epoch_62.hdf5
163/163 [==============================] - 88s 537ms/step - loss: 0.0612 -
acc: 0.9755 - val_loss: 0.0403 - val_acc: 1.0000
Epoch 63/100
162/163 [============================>.] - ETA: 0s - loss: 0.0672 - acc: 0
.9747Epoch 1/100
  1/163 [..............................] - ETA: 55s - loss: 0.0395 - acc:
1.0000
Epoch 00063: saving model to /content/data/model/weights.epoch_63.hdf5
163/163 [==============================] - 87s 533ms/step - loss: 0.0669 -
acc: 0.9749 - val_loss: 0.0395 - val_acc: 1.0000
Epoch 64/100
162/163 [============================>.] - ETA: 0s - loss: 0.0650 - acc: 0
.9759Epoch 1/100
  1/163 [..............................] - ETA: 55s - loss: 0.0335 - acc:
1.0000
Epoch 00064: saving model to /content/data/model/weights.epoch_64.hdf5
163/163 [==============================] - 86s 531ms/step - loss: 0.0646 -
acc: 0.9760 - val_loss: 0.0335 - val_acc: 1.0000
Epoch 65/100
162/163 [============================>.] - ETA: 0s - loss: 0.0661 - acc: 0
.9749Epoch 1/100
  1/163 [..............................] - ETA: 54s - loss: 0.0741 - acc:
1.0000
Epoch 00065: saving model to /content/data/model/weights.epoch_65.hdf5
163/163 [==============================] - 86s 528ms/step - loss: 0.0658 -
acc: 0.9751 - val_loss: 0.0741 - val_acc: 1.0000
Epoch 66/100
162/163 [============================>.] - ETA: 0s - loss: 0.0625 - acc: 0
.9751Epoch 1/100
  1/163 [..............................] - ETA: 54s - loss: 0.0522 - acc:
1.0000
Epoch 00066: saving model to /content/data/model/weights.epoch_66.hdf5
163/163 [==============================] - 87s 534ms/step - loss: 0.0625 -
acc: 0.9751 - val_loss: 0.0522 - val_acc: 1.0000
Epoch 67/100
162/163 [============================>.] - ETA: 0s - loss: 0.0681 - acc: 0
.9778Epoch 1/100
  1/163 [..............................] - ETA: 55s - loss: 0.0501 - acc:
1.0000
Epoch 00067: saving model to /content/data/model/weights.epoch_67.hdf5
163/163 [==============================] - 87s 531ms/step - loss: 0.0678 -
acc: 0.9780 - val_loss: 0.0501 - val_acc: 1.0000
Epoch 68/100
162/163 [============================>.] - ETA: 0s - loss: 0.0651 - acc: 0
.9778Epoch 1/100
  1/163 [..............................] - ETA: 55s - loss: 0.0337 - acc:
1.0000
Epoch 00068: saving model to /content/data/model/weights.epoch_68.hdf5
163/163 [==============================] - 87s 532ms/step - loss: 0.0648 -
acc: 0.9780 - val_loss: 0.0337 - val_acc: 1.0000
Epoch 69/100
162/163 [============================>.] - ETA: 0s - loss: 0.0629 - acc: 0
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.9765Epoch 1/100
  1/163 [..............................] - ETA: 54s - loss: 0.0396 - acc: 
1.0000
Epoch 00069: saving model to /content/data/model/weights.epoch_69.hdf5
163/163 [==============================] - 87s 534ms/step - loss: 0.0626 - 
acc: 0.9766 - val_loss: 0.0396 - val_acc: 1.0000
Epoch 70/100
162/163 [============================>.] - ETA: 0s - loss: 0.0592 - acc: 0
.9757Epoch 1/100
  1/163 [..............................] - ETA: 55s - loss: 0.0529 - acc: 
1.0000
Epoch 00070: saving model to /content/data/model/weights.epoch_70.hdf5
163/163 [==============================] - 87s 536ms/step - loss: 0.0589 - 
acc: 0.9758 - val_loss: 0.0529 - val_acc: 1.0000
Epoch 71/100
162/163 [============================>.] - ETA: 0s - loss: 0.0620 - acc: 0
.9780Epoch 1/100
  1/163 [..............................] - ETA: 56s - loss: 0.0662 - acc: 
1.0000
Epoch 00071: saving model to /content/data/model/weights.epoch_71.hdf5
163/163 [==============================] - 87s 532ms/step - loss: 0.0617 - 
acc: 0.9781 - val_loss: 0.0662 - val_acc: 1.0000
Epoch 72/100
162/163 [============================>.] - ETA: 0s - loss: 0.0620 - acc: 0
.9786Epoch 1/100
  1/163 [..............................] - ETA: 54s - loss: 0.0431 - acc: 
1.0000
Epoch 00072: saving model to /content/data/model/weights.epoch_72.hdf5
163/163 [==============================] - 87s 533ms/step - loss: 0.0618 - 
acc: 0.9787 - val_loss: 0.0431 - val_acc: 1.0000
Epoch 73/100
162/163 [============================>.] - ETA: 0s - loss: 0.0648 - acc: 0
.9765Epoch 1/100
  1/163 [..............................] - ETA: 56s - loss: 0.0710 - acc: 
1.0000
Epoch 00073: saving model to /content/data/model/weights.epoch_73.hdf5
163/163 [==============================] - 87s 536ms/step - loss: 0.0648 - 
acc: 0.9764 - val_loss: 0.0710 - val_acc: 1.0000
Epoch 74/100
162/163 [============================>.] - ETA: 0s - loss: 0.0655 - acc: 0
.9763Epoch 1/100
  1/163 [..............................] - ETA: 56s - loss: 0.0354 - acc: 
1.0000
Epoch 00074: saving model to /content/data/model/weights.epoch_74.hdf5
163/163 [==============================] - 87s 535ms/step - loss: 0.0651 - 
acc: 0.9764 - val_loss: 0.0354 - val_acc: 1.0000
Epoch 75/100
162/163 [============================>.] - ETA: 0s - loss: 0.0682 - acc: 0
.9761Epoch 1/100
  1/163 [..............................] - ETA: 57s - loss: 0.2922 - acc: 
0.8750
Epoch 00075: saving model to /content/data/model/weights.epoch_75.hdf5
163/163 [==============================] - 87s 532ms/step - loss: 0.0687 - 
acc: 0.9758 - val_loss: 0.2922 - val_acc: 0.8750
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Epoch 76/100
162/163 [============================>.] - ETA: 0s - loss: 0.0711 - acc: 0
.9734Epoch 1/100
  1/163 [..............................] - ETA: 56s - loss: 0.0363 - acc:
1.0000
Epoch 00076: saving model to /content/data/model/weights.epoch_76.hdf5
163/163 [==============================] - 86s 530ms/step - loss: 0.0707 -
acc: 0.9735 - val_loss: 0.0363 - val_acc: 1.0000
Epoch 77/100
162/163 [============================>.] - ETA: 0s - loss: 0.0657 - acc: 0
.9769Epoch 1/100
  1/163 [..............................] - ETA: 54s - loss: 0.0367 - acc:
1.0000
Epoch 00077: saving model to /content/data/model/weights.epoch_77.hdf5
163/163 [==============================] - 87s 533ms/step - loss: 0.0660 -
acc: 0.9766 - val_loss: 0.0367 - val_acc: 1.0000
Epoch 78/100
162/163 [============================>.] - ETA: 0s - loss: 0.0610 - acc: 0
.9811Epoch 1/100
  1/163 [..............................] - ETA: 54s - loss: 0.0346 - acc:
1.0000
Epoch 00078: saving model to /content/data/model/weights.epoch_78.hdf5
163/163 [==============================] - 87s 531ms/step - loss: 0.0608 -
acc: 0.9812 - val_loss: 0.0346 - val_acc: 1.0000
Epoch 79/100
162/163 [============================>.] - ETA: 0s - loss: 0.0591 - acc: 0
.9782Epoch 1/100
  1/163 [..............................] - ETA: 54s - loss: 0.0830 - acc:
0.9375
Epoch 00079: saving model to /content/data/model/weights.epoch_79.hdf5
163/163 [==============================] - 86s 530ms/step - loss: 0.0587 -
acc: 0.9783 - val_loss: 0.0830 - val_acc: 0.9375
Epoch 80/100
162/163 [============================>.] - ETA: 0s - loss: 0.0641 - acc: 0
.9738Epoch 1/100
  1/163 [..............................] - ETA: 55s - loss: 0.0763 - acc:
1.0000
Epoch 00080: saving model to /content/data/model/weights.epoch_80.hdf5
163/163 [==============================] - 87s 536ms/step - loss: 0.0637 -
acc: 0.9739 - val_loss: 0.0763 - val_acc: 1.0000
Epoch 81/100
162/163 [============================>.] - ETA: 0s - loss: 0.0575 - acc: 0
.9786Epoch 1/100
  1/163 [..............................] - ETA: 56s - loss: 0.0510 - acc:
1.0000
Epoch 00081: saving model to /content/data/model/weights.epoch_81.hdf5
163/163 [==============================] - 87s 537ms/step - loss: 0.0578 -
acc: 0.9785 - val_loss: 0.0510 - val_acc: 1.0000
Epoch 82/100
162/163 [============================>.] - ETA: 0s - loss: 0.0547 - acc: 0
.9788Epoch 1/100
  1/163 [..............................] - ETA: 54s - loss: 0.0347 - acc:
1.0000
Epoch 00082: saving model to /content/data/model/weights.epoch_82.hdf5
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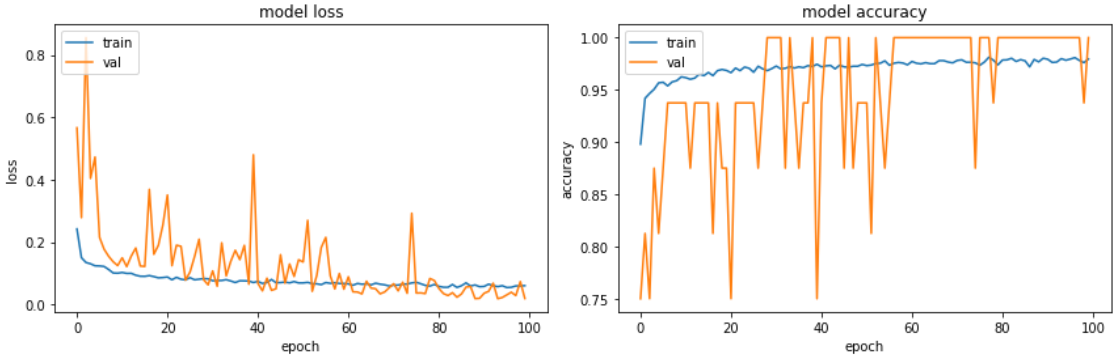
163/163 [==============================] - 87s 535ms/step - loss: 0.0548 -
acc: 0.9787 - val_loss: 0.0347 - val_acc: 1.0000
Epoch 83/100
162/163 [============================>.] - ETA: 0s - loss: 0.0550 - acc: 0
.9801Epoch 1/100
  1/163 [..............................] - ETA: 57s - loss: 0.0282 - acc:
1.0000
Epoch 00083: saving model to /content/data/model/weights.epoch_83.hdf5
163/163 [==============================] - 87s 535ms/step - loss: 0.0548 -
acc: 0.9803 - val_loss: 0.0282 - val_acc: 1.0000
Epoch 84/100
162/163 [============================>.] - ETA: 0s - loss: 0.0636 - acc: 0
.9772Epoch 1/100
  1/163 [..............................] - ETA: 58s - loss: 0.0374 - acc:
1.0000
Epoch 00084: saving model to /content/data/model/weights.epoch_84.hdf5
163/163 [==============================] - 88s 542ms/step - loss: 0.0637 -
acc: 0.9772 - val_loss: 0.0374 - val_acc: 1.0000
Epoch 85/100
162/163 [============================>.] - ETA: 0s - loss: 0.0544 - acc: 0
.9788Epoch 1/100
  1/163 [..............................] - ETA: 55s - loss: 0.0228 - acc:
1.0000
Epoch 00085: saving model to /content/data/model/weights.epoch_85.hdf5
163/163 [==============================] - 88s 539ms/step - loss: 0.0542 -
acc: 0.9789 - val_loss: 0.0228 - val_acc: 1.0000
Epoch 86/100
162/163 [============================>.] - ETA: 0s - loss: 0.0602 - acc: 0
.9776Epoch 1/100
  1/163 [..............................] - ETA: 53s - loss: 0.0334 - acc:
1.0000
Epoch 00086: saving model to /content/data/model/weights.epoch_86.hdf5
163/163 [==============================] - 87s 534ms/step - loss: 0.0599 -
acc: 0.9778 - val_loss: 0.0334 - val_acc: 1.0000
Epoch 87/100
162/163 [============================>.] - ETA: 0s - loss: 0.0678 - acc: 0
.9726Epoch 1/100
  1/163 [..............................] - ETA: 56s - loss: 0.0555 - acc:
1.0000
Epoch 00087: saving model to /content/data/model/weights.epoch_87.hdf5
163/163 [==============================] - 88s 538ms/step - loss: 0.0689 -
acc: 0.9720 - val_loss: 0.0555 - val_acc: 1.0000
Epoch 88/100
162/163 [============================>.] - ETA: 0s - loss: 0.0592 - acc: 0
.9790Epoch 1/100
  1/163 [..............................] - ETA: 55s - loss: 0.0570 - acc:
1.0000
Epoch 00088: saving model to /content/data/model/weights.epoch_88.hdf5
163/163 [==============================] - 89s 547ms/step - loss: 0.0589 -
acc: 0.9791 - val_loss: 0.0570 - val_acc: 1.0000
Epoch 89/100
162/163 [============================>.] - ETA: 0s - loss: 0.0624 - acc: 0
.9767Epoch 1/100
  1/163 [..............................] - ETA: 56s - loss: 0.0185 - acc:
```

```
1.0000
Epoch 00089: saving model to /content/data/model/weights.epoch_89.hdf5
163/163 [==============================] - 88s 542ms/step - loss: 0.0622 - acc: 0.9768 - val_loss: 0.0185 - val_acc: 1.0000
Epoch 90/100
162/163 [============================>.] - ETA: 0s - loss: 0.0569 - acc: 0.9801Epoch 1/100
  1/163 [..............................] - ETA: 54s - loss: 0.0194 - acc: 1.0000
Epoch 00090: saving model to /content/data/model/weights.epoch_90.hdf5
163/163 [==============================] - 88s 542ms/step - loss: 0.0566 - acc: 0.9803 - val_loss: 0.0194 - val_acc: 1.0000
Epoch 91/100
162/163 [============================>.] - ETA: 0s - loss: 0.0576 - acc: 0.9792Epoch 1/100
  1/163 [..............................] - ETA: 56s - loss: 0.0355 - acc: 1.0000
Epoch 00091: saving model to /content/data/model/weights.epoch_91.hdf5
163/163 [==============================] - 88s 543ms/step - loss: 0.0575 - acc: 0.9793 - val_loss: 0.0355 - val_acc: 1.0000
Epoch 92/100
162/163 [============================>.] - ETA: 0s - loss: 0.0651 - acc: 0.9761Epoch 1/100
  1/163 [..............................] - ETA: 56s - loss: 0.0418 - acc: 1.0000
Epoch 00092: saving model to /content/data/model/weights.epoch_92.hdf5
163/163 [==============================] - 89s 544ms/step - loss: 0.0648 - acc: 0.9762 - val_loss: 0.0418 - val_acc: 1.0000
Epoch 93/100
162/163 [============================>.] - ETA: 0s - loss: 0.0603 - acc: 0.9765Epoch 1/100
  1/163 [..............................] - ETA: 56s - loss: 0.0679 - acc: 1.0000
Epoch 00093: saving model to /content/data/model/weights.epoch_93.hdf5
163/163 [==============================] - 89s 548ms/step - loss: 0.0601 - acc: 0.9766 - val_loss: 0.0679 - val_acc: 1.0000
Epoch 94/100
162/163 [============================>.] - ETA: 0s - loss: 0.0567 - acc: 0.9799Epoch 1/100
  1/163 [..............................] - ETA: 56s - loss: 0.0181 - acc: 1.0000
Epoch 00094: saving model to /content/data/model/weights.epoch_94.hdf5
163/163 [==============================] - 89s 546ms/step - loss: 0.0568 - acc: 0.9799 - val_loss: 0.0181 - val_acc: 1.0000
Epoch 95/100
162/163 [============================>.] - ETA: 0s - loss: 0.0600 - acc: 0.9784Epoch 1/100
  1/163 [..............................] - ETA: 1:00 - loss: 0.0219 - acc: 1.0000
Epoch 00095: saving model to /content/data/model/weights.epoch_95.hdf5
163/163 [==============================] - 89s 547ms/step - loss: 0.0599 - acc: 0.9783 - val_loss: 0.0219 - val_acc: 1.0000
Epoch 96/100
162/163 [============================>.] - ETA: 0s - loss: 0.0541 - acc: 0
```

```
.9794Epoch 1/100
  1/163 [..............................] - ETA: 57s - loss: 0.0304 - acc:
1.0000
Epoch 00096: saving model to /content/data/model/weights.epoch_96.hdf5
163/163 [==============================] - 89s 545ms/step - loss: 0.0540 -
acc: 0.9795 - val_loss: 0.0304 - val_acc: 1.0000
Epoch 97/100
162/163 [============================>.] - ETA: 0s - loss: 0.0550 - acc: 0
.9807Epoch 1/100
  1/163 [..............................] - ETA: 59s - loss: 0.0389 - acc:
1.0000
Epoch 00097: saving model to /content/data/model/weights.epoch_97.hdf5
163/163 [==============================] - 89s 547ms/step - loss: 0.0547 -
acc: 0.9808 - val_loss: 0.0389 - val_acc: 1.0000
Epoch 98/100
162/163 [============================>.] - ETA: 0s - loss: 0.0595 - acc: 0
.9780Epoch 1/100
  1/163 [..............................] - ETA: 55s - loss: 0.0282 - acc:
1.0000
Epoch 00098: saving model to /content/data/model/weights.epoch_98.hdf5
163/163 [==============================] - 89s 548ms/step - loss: 0.0592 -
acc: 0.9781 - val_loss: 0.0282 - val_acc: 1.0000
Epoch 99/100
162/163 [============================>.] - ETA: 0s - loss: 0.0593 - acc: 0
.9759Epoch 1/100
  1/163 [..............................] - ETA: 55s - loss: 0.0730 - acc:
0.9375
Epoch 00099: saving model to /content/data/model/weights.epoch_99.hdf5
163/163 [==============================] - 90s 551ms/step - loss: 0.0591 -
acc: 0.9760 - val_loss: 0.0730 - val_acc: 0.9375
Epoch 100/100
162/163 [============================>.] - ETA: 0s - loss: 0.0603 - acc: 0
.9794Epoch 1/100
  1/163 [..............................] - ETA: 56s - loss: 0.0189 - acc:
1.0000
Epoch 00100: saving model to /content/data/model/weights.epoch_100.hdf5
163/163 [==============================] - 90s 550ms/step - loss: 0.0601 -
acc: 0.9795 - val_loss: 0.0189 - val_acc: 1.0000
20/20 [==============================] - 8s 383ms/step - loss: 0.3198 - ac
c: 0.9087
Loading the best model
epoch: 94, val_loss: 0.01814509741961956, val_acc: 1.0
20/20 [==============================] - 7s 363ms/step - loss: 0.3109 - ac
c: 0.9167
20/20 [==============================] - 8s 394ms/step
CONFUSION MATRIX ------------------
[[201  33]
 [ 19 371]]

TEST METRICS ----------------------
Accuracy: 91.66666666666666%
Precision: 91.83168316831683%
Recall: 95.12820512820512%
F1-score: 93.45088161209067
```

```
TRAIN METRIC ----------------------
Train acc: 97.94861674308775%
```



png

```
## Load best weight
idx = np.argmin(history.history['acc'])
model.load_weights("/content/data/model/weights.epoch_{:02d}.hdf5".format(
idx + 1))

print("Loading the best model")
print("epoch: {}, val_loss: {}, val_acc: {}".format(idx + 1, history.histo
ry['val_loss'][idx], history.history['val_acc'][idx]))

## Evaluate the best weight
test_loss, test_acc = model.evaluate_generator(generator=test_generator, v
erbose=1)

## Test analytics
from sklearn.metrics import accuracy_score, confusion_matrix

test_generator.reset()
test_preds = model.predict_generator(test_generator, verbose=1)
test_preds = np.argmax(test_preds,axis=1)

acc = accuracy_score(test_generator.classes, test_preds)*100
cm = confusion_matrix(test_generator.classes, test_preds)
tn, fp, fn, tp = cm.ravel()

print('CONFUSION MATRIX ------------------')
print(cm)
# plot_confusion_matrix(cm, target_names=['NORMAL', 'PNEUMONIA'], normaliz
e=False)


print('\nTEST METRICS ----------------------')
precision = tp/(tp+fp)*100
recall = tp/(tp+fn)*100
print('Accuracy: {}%'.format(acc))
print('Precision: {}%'.format(precision))
print('Recall: {}%'.format(recall))
print('F1-score: {}'.format(2*precision*recall/(precision+recall)))
```

```
print('\nTRAIN METRIC ----------------------')
print('Train acc: {}%'.format(np.round((history.history['acc'][-1])*100, 1
4)))
```

```
Loading the best model
epoch: 1, val_loss: 0.5660557150840759, val_acc: 0.75
20/20 [==============================] - 7s 349ms/step - loss: 0.3333 - ac
c: 0.8622
20/20 [==============================] - 7s 365ms/step
CONFUSION MATRIX ------------------
[[154  80]
 [  6 384]]

TEST METRICS ----------------------
Accuracy: 86.21794871794873%
Precision: 82.75862068965517%
Recall: 98.46153846153847%
F1-score: 89.9297423887588

TRAIN METRIC ----------------------
Train acc: 97.94861674308775%
```

9.4 *Appendix D: VGG16 Model 1 Version 1.1.1.0.0*

```
from __future__ import absolute_import, division, print_function, unicode_
literals
import tensorflow as tf

# Extract dataset
import os
import tarfile

import keras_preprocessing
from keras_preprocessing.image import ImageDataGenerator # Data preprocess
ing and augmentation

import sklearn
import numpy as np
```

The default version of TensorFlow in Colab will soon switch to TensorFlow 2.x. We recommend you upgrade now or ensure your notebook will continue to use TensorFlow 1.x via the %tensorflow_version 1.x magic: more info.

```
print(tf.__version__)
```

```
1.15.0
```

```
# Make folder for chest xray data
!mkdir /content/data/

# Make directory to save weights
!mkdir /content/data/model

# Make directory to logs for Tensorboard
!mkdir /content/data/graph

# Download dataset
!wget --no-check-certificate \
    https://s3.eu-central-1.amazonaws.com/public.unit8.co/data/chest_xray.
tar.gz \
    -O /content/data/chest_xray.tar.gz

tar = tarfile.open("data/chest_xray.tar.gz")
tar.extractall(path='./data/')
os.remove('data/chest_xray.tar.gz')
```

```
--2019-10-28 09:05:47--  https://s3.eu-central-1.amazonaws.com/public.unit
8.co/data/chest_xray.tar.gz
Resolving s3.eu-central-1.amazonaws.com (s3.eu-central-1.amazonaws.com)...
52.219.73.147
Connecting to s3.eu-central-1.amazonaws.com (s3.eu-central-1.amazonaws.com
)|52.219.73.147|:443... connected.
HTTP request sent, awaiting response... 200 OK
Length: 1225393795 (1.1G) [application/x-gzip]
```

```
Saving to: ‘/content/data/chest_xray.tar.gz’

/content/data/chest 100%[===================>]   1.14G  11.5MB/s    in 1m
45s

2019-10-28 09:07:33 (11.1 MB/s) - ‘/content/data/chest_xray.tar.gz’ saved
[1225393795/1225393795]

----
```

Change log: > training_datagen –> ImageDataGenerator

trainable layer –> All except base

20 layers VGG16 model - base, flat, dense

Optimizer = RMSprop(learning_rate = 0.0001)

loss = categorical_crosscentropy

callback = [checkpoints]

epochs = 100

no class weight balancing

```
TRAINING_DIR = "/content/data/chest_xray/train"
VALIDATION_DIR = "/content/data/chest_xray/val"
TEST_DIR = "/content/data/chest_xray/test"

training_datagen = ImageDataGenerator(
    preprocessing_function=tf.keras.applications.vgg16.preprocess_input,
    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,
    # vertical_flip=True
    fill_mode='nearest'
)

validation_datagen = ImageDataGenerator(
    rescale = 1./255
)

test_datagen = ImageDataGenerator(
    rescale = 1./255
)

# Create training data batch
# TODO: Try grayscaling the image to see what will happen
train_generator = training_datagen.flow_from_directory(
    TRAINING_DIR,
```

```
    target_size=(150,150),
    class_mode='categorical'
)

validation_generator = validation_datagen.flow_from_directory(
    VALIDATION_DIR,
    target_size=(150,150),
    class_mode='categorical'
)

test_generator = test_datagen.flow_from_directory(
    TEST_DIR,
    target_size=(150,150),
    class_mode='categorical',
    shuffle=False
)

train_shape = train_generator.image_shape

tf.keras.backend.clear_session() # Destroys the current TF graph and creat
es a new one.

base_model = tf.keras.applications.VGG16(weights='imagenet', include_top=F
alse, input_shape=train_shape)

# Define the machine learning model
x = base_model.output
x = tf.keras.layers.Flatten()(x)
x = tf.keras.layers.Dense(2, 'softmax')(x)

model = tf.keras.Model(inputs=base_model.input, outputs=x)

# for layer in model.layers[0:20]:
#     layer.trainable = False

for layer in base_model.layers:
  layer.trainable = False

optimizer = tf.keras.optimizers.RMSprop(learning_rate=0.0001) # Lower lear
ning rate by x10

model.compile(loss='categorical_crossentropy',
              optimizer=optimizer,
              metrics=['accuracy'])

# Callbacks stuff
# Function to save the weights of the model after each epoch
checkpoint = tf.keras.callbacks.ModelCheckpoint(
    '/content/data/model/weights.epoch_{epoch:02d}.hdf5',
    monitor='val_accuracy',
    save_best_only=False,
    save_weights_only=False,
    mode='auto',
    verbose=1
```

```
)

# Function to stop training early if there's no improvement
early_stopping_monitor = tf.keras.callbacks.EarlyStopping(patience = 3, mo
nitor = "val_loss", mode="auto", verbose = 1)

lr_reduce = tf.keras.callbacks.ReduceLROnPlateau(monitor='val_loss', facto
r=0.3, patience=2, verbose=1, mode='max')

classweight = sklearn.utils.class_weight.compute_class_weight('balanced',
np.unique(train_generator.labels), train_generator.labels)
print(classweight)

batch_size = 32
epochs = 100

# Training process
history = model.fit_generator(
    generator=train_generator,
    # steps_per_epoch=train_generator.samples//batch_size,
    epochs=epochs,
    # callbacks=[early_stopping_monitor],
    callbacks=[checkpoint],
    # shuffle=True,
    validation_data=validation_generator,
    # validation_steps= validation_generator//batch_size, #no because it's
gonna be 0... if leave alone its len(generator) which is equal to 1.
    # class_weight=classweight,
    verbose = 1
)

# test_loss, test_acc = model.evaluate_generator(generator=test_generator,
verbose=1)
```

```
Found 5216 images belonging to 2 classes.
Found 16 images belonging to 2 classes.
Found 624 images belonging to 2 classes.
WARNING:tensorflow:From /usr/local/lib/python3.6/dist-packages/tensorflow_
core/python/ops/resource_variable_ops.py:1630: calling BaseResourceVariabl
e.__init__ (from tensorflow.python.ops.resource_variable_ops) with constra
int is deprecated and will be removed in a future version.
Instructions for updating:
If using Keras pass *_constraint arguments to layers.
Downloading data from https://github.com/fchollet/deep-learning-models/rel
eases/download/v0.1/vgg16_weights_tf_dim_ordering_tf_kernels_notop.h5
58892288/58889256 [==============================] - 5s 0us/step
[1.9448173  0.67303226]
Epoch 1/100
162/163 [============================>.] - ETA: 0s - loss: 0.3272 - acc: 0
.8611Epoch 1/100
  1/163 [..............................] - ETA: 4:26 - loss: 0.3919 - acc:
0.8125
Epoch 00001: saving model to /content/data/model/weights.epoch_01.hdf5
163/163 [==============================] - 89s 546ms/step - loss: 0.3262 -
```

```
acc: 0.8616 - val_loss: 0.3919 - val_acc: 0.8125
Epoch 2/100
162/163 [============================>.] - ETA: 0s - loss: 0.1985 - acc: 0
.9306Epoch 1/100
  1/163 [..............................] - ETA: 55s - loss: 0.3267 - acc:
0.8750
Epoch 00002: saving model to /content/data/model/weights.epoch_02.hdf5
163/163 [==============================] - 85s 523ms/step - loss: 0.1994 -
acc: 0.9300 - val_loss: 0.3267 - val_acc: 0.8750
Epoch 3/100
162/163 [============================>.] - ETA: 0s - loss: 0.1699 - acc: 0
.9392Epoch 1/100
  1/163 [..............................] - ETA: 56s - loss: 0.3100 - acc:
0.8750
Epoch 00003: saving model to /content/data/model/weights.epoch_03.hdf5
163/163 [==============================] - 86s 529ms/step - loss: 0.1695 -
acc: 0.9394 - val_loss: 0.3100 - val_acc: 0.8750
Epoch 4/100
162/163 [============================>.] - ETA: 0s - loss: 0.1526 - acc: 0
.9441Epoch 1/100
  1/163 [..............................] - ETA: 57s - loss: 0.3196 - acc:
0.8750
Epoch 00004: saving model to /content/data/model/weights.epoch_04.hdf5
163/163 [==============================] - 87s 532ms/step - loss: 0.1521 -
acc: 0.9444 - val_loss: 0.3196 - val_acc: 0.8750
Epoch 5/100
162/163 [============================>.] - ETA: 0s - loss: 0.1438 - acc: 0
.9443Epoch 1/100
  1/163 [..............................] - ETA: 54s - loss: 0.4042 - acc:
0.8125
Epoch 00005: saving model to /content/data/model/weights.epoch_05.hdf5
163/163 [==============================] - 86s 528ms/step - loss: 0.1442 -
acc: 0.9440 - val_loss: 0.4042 - val_acc: 0.8125
Epoch 6/100
162/163 [============================>.] - ETA: 0s - loss: 0.1353 - acc: 0
.9493Epoch 1/100
  1/163 [..............................] - ETA: 55s - loss: 0.2808 - acc:
0.8125
Epoch 00006: saving model to /content/data/model/weights.epoch_06.hdf5
163/163 [==============================] - 87s 534ms/step - loss: 0.1363 -
acc: 0.9486 - val_loss: 0.2808 - val_acc: 0.8125
Epoch 7/100
162/163 [============================>.] - ETA: 0s - loss: 0.1350 - acc: 0
.9529Epoch 1/100
  1/163 [..............................] - ETA: 1:00 - loss: 0.3641 - acc:
0.8125
Epoch 00007: saving model to /content/data/model/weights.epoch_07.hdf5
163/163 [==============================] - 86s 525ms/step - loss: 0.1348 -
acc: 0.9528 - val_loss: 0.3641 - val_acc: 0.8125
Epoch 8/100
162/163 [============================>.] - ETA: 0s - loss: 0.1300 - acc: 0
.9504Epoch 1/100
  1/163 [..............................] - ETA: 54s - loss: 0.3363 - acc:
0.8750
```

```
Epoch 00008: saving model to /content/data/model/weights.epoch_08.hdf5
163/163 [==============================] - 87s 535ms/step - loss: 0.1302 -
acc: 0.9503 - val_loss: 0.3363 - val_acc: 0.8750
Epoch 9/100
162/163 [============================>.] - ETA: 0s - loss: 0.1273 - acc: 0
.9520Epoch 1/100
  1/163 [..............................] - ETA: 53s - loss: 0.3568 - acc:
0.8125
Epoch 00009: saving model to /content/data/model/weights.epoch_09.hdf5
163/163 [==============================] - 87s 531ms/step - loss: 0.1276 -
acc: 0.9519 - val_loss: 0.3568 - val_acc: 0.8125
Epoch 10/100
162/163 [============================>.] - ETA: 0s - loss: 0.1233 - acc: 0
.9558Epoch 1/100
  1/163 [..............................] - ETA: 58s - loss: 0.3402 - acc:
0.8750
Epoch 00010: saving model to /content/data/model/weights.epoch_10.hdf5
163/163 [==============================] - 87s 536ms/step - loss: 0.1237 -
acc: 0.9553 - val_loss: 0.3402 - val_acc: 0.8750
Epoch 11/100
162/163 [============================>.] - ETA: 0s - loss: 0.1201 - acc: 0
.9562Epoch 1/100
  1/163 [..............................] - ETA: 54s - loss: 0.2826 - acc:
0.8125
Epoch 00011: saving model to /content/data/model/weights.epoch_11.hdf5
163/163 [==============================] - 87s 536ms/step - loss: 0.1205 -
acc: 0.9555 - val_loss: 0.2826 - val_acc: 0.8125
Epoch 12/100
162/163 [============================>.] - ETA: 0s - loss: 0.1174 - acc: 0
.9566Epoch 1/100
  1/163 [..............................] - ETA: 56s - loss: 0.2523 - acc:
0.8125
Epoch 00012: saving model to /content/data/model/weights.epoch_12.hdf5
163/163 [==============================] - 87s 537ms/step - loss: 0.1175 -
acc: 0.9565 - val_loss: 0.2523 - val_acc: 0.8125
Epoch 13/100
162/163 [============================>.] - ETA: 0s - loss: 0.1190 - acc: 0
.9543Epoch 1/100
  1/163 [..............................] - ETA: 54s - loss: 0.3225 - acc:
0.8750
Epoch 00013: saving model to /content/data/model/weights.epoch_13.hdf5
163/163 [==============================] - 87s 533ms/step - loss: 0.1186 -
acc: 0.9546 - val_loss: 0.3225 - val_acc: 0.8750
Epoch 14/100
162/163 [============================>.] - ETA: 0s - loss: 0.1149 - acc: 0
.9593Epoch 1/100
  1/163 [..............................] - ETA: 59s - loss: 0.3168 - acc:
0.8750
Epoch 00014: saving model to /content/data/model/weights.epoch_14.hdf5
163/163 [==============================] - 88s 537ms/step - loss: 0.1154 -
acc: 0.9586 - val_loss: 0.3168 - val_acc: 0.8750
Epoch 15/100
162/163 [============================>.] - ETA: 0s - loss: 0.1174 - acc: 0
.9579Epoch 1/100
```

```
  1/163 [..............................] - ETA: 55s - loss: 0.2474 - acc:
0.8125
Epoch 00015: saving model to /content/data/model/weights.epoch_15.hdf5
163/163 [==============================] - 87s 536ms/step - loss: 0.1180 -
acc: 0.9574 - val_loss: 0.2474 - val_acc: 0.8125
Epoch 16/100
162/163 [============================>.] - ETA: 0s - loss: 0.1118 - acc: 0
.9579Epoch 1/100
  1/163 [..............................] - ETA: 56s - loss: 0.2492 - acc:
0.8125
Epoch 00016: saving model to /content/data/model/weights.epoch_16.hdf5
163/163 [==============================] - 88s 539ms/step - loss: 0.1121 -
acc: 0.9578 - val_loss: 0.2492 - val_acc: 0.8125
Epoch 17/100
162/163 [============================>.] - ETA: 0s - loss: 0.1108 - acc: 0
.9616Epoch 1/100
  1/163 [..............................] - ETA: 54s - loss: 0.2344 - acc:
0.8125
Epoch 00017: saving model to /content/data/model/weights.epoch_17.hdf5
163/163 [==============================] - 86s 529ms/step - loss: 0.1103 -
acc: 0.9618 - val_loss: 0.2344 - val_acc: 0.8125
Epoch 18/100
162/163 [============================>.] - ETA: 0s - loss: 0.1063 - acc: 0
.9606Epoch 1/100
  1/163 [..............................] - ETA: 52s - loss: 0.2972 - acc:
0.8750
Epoch 00018: saving model to /content/data/model/weights.epoch_18.hdf5
163/163 [==============================] - 85s 522ms/step - loss: 0.1061 -
acc: 0.9607 - val_loss: 0.2972 - val_acc: 0.8750
Epoch 19/100
162/163 [============================>.] - ETA: 0s - loss: 0.1107 - acc: 0
.9599Epoch 1/100
  1/163 [..............................] - ETA: 53s - loss: 0.2626 - acc:
0.8750
Epoch 00019: saving model to /content/data/model/weights.epoch_19.hdf5
163/163 [==============================] - 85s 520ms/step - loss: 0.1105 -
acc: 0.9599 - val_loss: 0.2626 - val_acc: 0.8750
Epoch 20/100
162/163 [============================>.] - ETA: 0s - loss: 0.1058 - acc: 0
.9639Epoch 1/100
  1/163 [..............................] - ETA: 53s - loss: 0.3010 - acc:
0.8750
Epoch 00020: saving model to /content/data/model/weights.epoch_20.hdf5
163/163 [==============================] - 85s 522ms/step - loss: 0.1056 -
acc: 0.9641 - val_loss: 0.3010 - val_acc: 0.8750
Epoch 21/100
162/163 [============================>.] - ETA: 0s - loss: 0.1055 - acc: 0
.9614Epoch 1/100
  1/163 [..............................] - ETA: 55s - loss: 0.2826 - acc:
0.8750
Epoch 00021: saving model to /content/data/model/weights.epoch_21.hdf5
163/163 [==============================] - 83s 509ms/step - loss: 0.1058 -
acc: 0.9613 - val_loss: 0.2826 - val_acc: 0.8750
Epoch 22/100
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162/163 [============================>.] - ETA: 0s - loss: 0.1095 - acc: 0
.9605Epoch 1/100
  1/163 [..............................] - ETA: 54s - loss: 0.2716 - acc:
0.8750
Epoch 00022: saving model to /content/data/model/weights.epoch_22.hdf5
163/163 [==============================] - 83s 510ms/step - loss: 0.1092 -
acc: 0.9605 - val_loss: 0.2716 - val_acc: 0.8750
Epoch 23/100
162/163 [============================>.] - ETA: 0s - loss: 0.1034 - acc: 0
.9608Epoch 1/100
  1/163 [..............................] - ETA: 54s - loss: 0.2642 - acc:
0.8750
Epoch 00023: saving model to /content/data/model/weights.epoch_23.hdf5
163/163 [==============================] - 83s 510ms/step - loss: 0.1033 -
acc: 0.9609 - val_loss: 0.2642 - val_acc: 0.8750
Epoch 24/100
162/163 [============================>.] - ETA: 0s - loss: 0.1060 - acc: 0
.9605Epoch 1/100
  1/163 [..............................] - ETA: 54s - loss: 0.2502 - acc:
0.8750
Epoch 00024: saving model to /content/data/model/weights.epoch_24.hdf5
163/163 [==============================] - 82s 504ms/step - loss: 0.1057 -
acc: 0.9607 - val_loss: 0.2502 - val_acc: 0.8750
Epoch 25/100
162/163 [============================>.] - ETA: 0s - loss: 0.0994 - acc: 0
.9622Epoch 1/100
  1/163 [..............................] - ETA: 54s - loss: 0.2606 - acc:
0.8750
Epoch 00025: saving model to /content/data/model/weights.epoch_25.hdf5
163/163 [==============================] - 82s 503ms/step - loss: 0.1000 -
acc: 0.9618 - val_loss: 0.2606 - val_acc: 0.8750
Epoch 26/100
162/163 [============================>.] - ETA: 0s - loss: 0.0993 - acc: 0
.9622Epoch 1/100
  1/163 [..............................] - ETA: 54s - loss: 0.2393 - acc:
0.8125
Epoch 00026: saving model to /content/data/model/weights.epoch_26.hdf5
163/163 [==============================] - 82s 505ms/step - loss: 0.0989 -
acc: 0.9624 - val_loss: 0.2393 - val_acc: 0.8125
Epoch 27/100
162/163 [============================>.] - ETA: 0s - loss: 0.0994 - acc: 0
.9659Epoch 1/100
  1/163 [..............................] - ETA: 55s - loss: 0.2544 - acc:
0.8750
Epoch 00027: saving model to /content/data/model/weights.epoch_27.hdf5
163/163 [==============================] - 84s 518ms/step - loss: 0.0997 -
acc: 0.9659 - val_loss: 0.2544 - val_acc: 0.8750
Epoch 28/100
162/163 [============================>.] - ETA: 0s - loss: 0.1002 - acc: 0
.9635Epoch 1/100
  1/163 [..............................] - ETA: 57s - loss: 0.2212 - acc:
0.8125
Epoch 00028: saving model to /content/data/model/weights.epoch_28.hdf5
163/163 [==============================] - 87s 533ms/step - loss: 0.1002 -
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acc: 0.9634 - val_loss: 0.2212 - val_acc: 0.8125
Epoch 29/100
162/163 [============================>.] - ETA: 0s - loss: 0.1051 - acc: 0
.9620Epoch 1/100
  1/163 [..............................] - ETA: 54s - loss: 0.2403 - acc:
0.8750
Epoch 00029: saving model to /content/data/model/weights.epoch_29.hdf5
163/163 [==============================] - 88s 537ms/step - loss: 0.1049 -
acc: 0.9622 - val_loss: 0.2403 - val_acc: 0.8750
Epoch 30/100
162/163 [============================>.] - ETA: 0s - loss: 0.0953 - acc: 0
.9632Epoch 1/100
  1/163 [..............................] - ETA: 56s - loss: 0.2363 - acc:
0.8125
Epoch 00030: saving model to /content/data/model/weights.epoch_30.hdf5
163/163 [==============================] - 88s 538ms/step - loss: 0.0958 -
acc: 0.9632 - val_loss: 0.2363 - val_acc: 0.8125
Epoch 31/100
162/163 [============================>.] - ETA: 0s - loss: 0.1003 - acc: 0
.9645Epoch 1/100
  1/163 [..............................] - ETA: 54s - loss: 0.2638 - acc:
0.8750
Epoch 00031: saving model to /content/data/model/weights.epoch_31.hdf5
163/163 [==============================] - 87s 536ms/step - loss: 0.1003 -
acc: 0.9645 - val_loss: 0.2638 - val_acc: 0.8750
Epoch 32/100
162/163 [============================>.] - ETA: 0s - loss: 0.0993 - acc: 0
.9601Epoch 1/100
  1/163 [..............................] - ETA: 57s - loss: 0.2800 - acc:
0.8750
Epoch 00032: saving model to /content/data/model/weights.epoch_32.hdf5
163/163 [==============================] - 87s 534ms/step - loss: 0.0995 -
acc: 0.9599 - val_loss: 0.2800 - val_acc: 0.8750
Epoch 33/100
162/163 [============================>.] - ETA: 0s - loss: 0.0931 - acc: 0
.9657Epoch 1/100
  1/163 [..............................] - ETA: 53s - loss: 0.1983 - acc:
0.8125
Epoch 00033: saving model to /content/data/model/weights.epoch_33.hdf5
163/163 [==============================] - 88s 539ms/step - loss: 0.0931 -
acc: 0.9657 - val_loss: 0.1983 - val_acc: 0.8125
Epoch 34/100
162/163 [============================>.] - ETA: 0s - loss: 0.0919 - acc: 0
.9684Epoch 1/100
  1/163 [..............................] - ETA: 57s - loss: 0.2493 - acc:
0.8750
Epoch 00034: saving model to /content/data/model/weights.epoch_34.hdf5
163/163 [==============================] - 87s 537ms/step - loss: 0.0916 -
acc: 0.9686 - val_loss: 0.2493 - val_acc: 0.8750
Epoch 35/100
162/163 [============================>.] - ETA: 0s - loss: 0.0941 - acc: 0
.9655Epoch 1/100
  1/163 [..............................] - ETA: 55s - loss: 0.2328 - acc:
0.8750
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Epoch 00035: saving model to /content/data/model/weights.epoch_35.hdf5
163/163 [==============================] - 88s 538ms/step - loss: 0.0940 -
acc: 0.9655 - val_loss: 0.2328 - val_acc: 0.8750
Epoch 36/100
162/163 [============================>.] - ETA: 0s - loss: 0.0957 - acc: 0
.9660Epoch 1/100
  1/163 [..............................] - ETA: 56s - loss: 0.2161 - acc:
0.8750
Epoch 00036: saving model to /content/data/model/weights.epoch_36.hdf5
163/163 [==============================] - 88s 540ms/step - loss: 0.0958 -
acc: 0.9661 - val_loss: 0.2161 - val_acc: 0.8750
Epoch 37/100
162/163 [============================>.] - ETA: 0s - loss: 0.0919 - acc: 0
.9660Epoch 1/100
  1/163 [..............................] - ETA: 56s - loss: 0.1894 - acc:
0.8125
Epoch 00037: saving model to /content/data/model/weights.epoch_37.hdf5
163/163 [==============================] - 88s 541ms/step - loss: 0.0918 -
acc: 0.9661 - val_loss: 0.1894 - val_acc: 0.8125
Epoch 38/100
162/163 [============================>.] - ETA: 0s - loss: 0.0915 - acc: 0
.9662Epoch 1/100
  1/163 [..............................] - ETA: 53s - loss: 0.2136 - acc:
0.8750
Epoch 00038: saving model to /content/data/model/weights.epoch_38.hdf5
163/163 [==============================] - 88s 539ms/step - loss: 0.0914 -
acc: 0.9663 - val_loss: 0.2136 - val_acc: 0.8750
Epoch 39/100
162/163 [============================>.] - ETA: 0s - loss: 0.0902 - acc: 0
.9649Epoch 1/100
  1/163 [..............................] - ETA: 56s - loss: 0.2224 - acc:
0.8750
Epoch 00039: saving model to /content/data/model/weights.epoch_39.hdf5
163/163 [==============================] - 88s 539ms/step - loss: 0.0901 -
acc: 0.9649 - val_loss: 0.2224 - val_acc: 0.8750
Epoch 40/100
162/163 [============================>.] - ETA: 0s - loss: 0.0947 - acc: 0
.9632Epoch 1/100
  1/163 [..............................] - ETA: 56s - loss: 0.2040 - acc:
0.8125
Epoch 00040: saving model to /content/data/model/weights.epoch_40.hdf5
163/163 [==============================] - 88s 542ms/step - loss: 0.0945 -
acc: 0.9632 - val_loss: 0.2040 - val_acc: 0.8125
Epoch 41/100
162/163 [============================>.] - ETA: 0s - loss: 0.0941 - acc: 0
.9616Epoch 1/100
  1/163 [..............................] - ETA: 57s - loss: 0.2177 - acc:
0.8750
Epoch 00041: saving model to /content/data/model/weights.epoch_41.hdf5
163/163 [==============================] - 88s 542ms/step - loss: 0.0944 -
acc: 0.9615 - val_loss: 0.2177 - val_acc: 0.8750
Epoch 42/100
162/163 [============================>.] - ETA: 0s - loss: 0.0937 - acc: 0
.9649Epoch 1/100
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  1/163 [..............................] - ETA: 57s - loss: 0.1838 - acc:
0.8750
Epoch 00042: saving model to /content/data/model/weights.epoch_42.hdf5
163/163 [==============================] - 88s 542ms/step - loss: 0.0937 -
acc: 0.9649 - val_loss: 0.1838 - val_acc: 0.8750
Epoch 43/100
162/163 [============================>.] - ETA: 0s - loss: 0.0897 - acc: 0
.9668Epoch 1/100
  1/163 [..............................] - ETA: 55s - loss: 0.1971 - acc:
0.8750
Epoch 00043: saving model to /content/data/model/weights.epoch_43.hdf5
163/163 [==============================] - 88s 542ms/step - loss: 0.0892 -
acc: 0.9670 - val_loss: 0.1971 - val_acc: 0.8750
Epoch 44/100
162/163 [============================>.] - ETA: 0s - loss: 0.0882 - acc: 0
.9689Epoch 1/100
  1/163 [..............................] - ETA: 57s - loss: 0.1768 - acc:
0.9375
Epoch 00044: saving model to /content/data/model/weights.epoch_44.hdf5
163/163 [==============================] - 88s 541ms/step - loss: 0.0882 -
acc: 0.9689 - val_loss: 0.1768 - val_acc: 0.9375
Epoch 45/100
162/163 [============================>.] - ETA: 0s - loss: 0.0877 - acc: 0
.9688Epoch 1/100
  1/163 [..............................] - ETA: 58s - loss: 0.2417 - acc:
0.8750
Epoch 00045: saving model to /content/data/model/weights.epoch_45.hdf5
163/163 [==============================] - 89s 544ms/step - loss: 0.0877 -
acc: 0.9686 - val_loss: 0.2417 - val_acc: 0.8750
Epoch 46/100
162/163 [============================>.] - ETA: 0s - loss: 0.0915 - acc: 0
.9676Epoch 1/100
  1/163 [..............................] - ETA: 56s - loss: 0.1968 - acc:
0.8125
Epoch 00046: saving model to /content/data/model/weights.epoch_46.hdf5
163/163 [==============================] - 89s 545ms/step - loss: 0.0923 -
acc: 0.9672 - val_loss: 0.1968 - val_acc: 0.8125
Epoch 47/100
162/163 [============================>.] - ETA: 0s - loss: 0.0865 - acc: 0
.9670Epoch 1/100
  1/163 [..............................] - ETA: 56s - loss: 0.1954 - acc:
0.8125
Epoch 00047: saving model to /content/data/model/weights.epoch_47.hdf5
163/163 [==============================] - 89s 543ms/step - loss: 0.0874 -
acc: 0.9664 - val_loss: 0.1954 - val_acc: 0.8125
Epoch 48/100
162/163 [============================>.] - ETA: 0s - loss: 0.0910 - acc: 0
.9676Epoch 1/100
  1/163 [..............................] - ETA: 54s - loss: 0.1813 - acc:
0.8750
Epoch 00048: saving model to /content/data/model/weights.epoch_48.hdf5
163/163 [==============================] - 89s 544ms/step - loss: 0.0906 -
acc: 0.9678 - val_loss: 0.1813 - val_acc: 0.8750
Epoch 49/100
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162/163 [============================>.] - ETA: 0s - loss: 0.0864 - acc: 0
.9691Epoch 1/100
  1/163 [..............................] - ETA: 56s - loss: 0.1764 - acc:
0.9375
Epoch 00049: saving model to /content/data/model/weights.epoch_49.hdf5
163/163 [==============================] - 88s 540ms/step - loss: 0.0867 -
acc: 0.9689 - val_loss: 0.1764 - val_acc: 0.9375
Epoch 50/100
162/163 [============================>.] - ETA: 0s - loss: 0.0837 - acc: 0
.9701Epoch 1/100
  1/163 [..............................] - ETA: 53s - loss: 0.1720 - acc:
0.9375
Epoch 00050: saving model to /content/data/model/weights.epoch_50.hdf5
163/163 [==============================] - 87s 536ms/step - loss: 0.0835 -
acc: 0.9703 - val_loss: 0.1720 - val_acc: 0.9375
Epoch 51/100
162/163 [============================>.] - ETA: 0s - loss: 0.0838 - acc: 0
.9693Epoch 1/100
  1/163 [..............................] - ETA: 57s - loss: 0.1691 - acc:
0.8750
Epoch 00051: saving model to /content/data/model/weights.epoch_51.hdf5
163/163 [==============================] - 88s 542ms/step - loss: 0.0834 -
acc: 0.9695 - val_loss: 0.1691 - val_acc: 0.8750
Epoch 52/100
162/163 [============================>.] - ETA: 0s - loss: 0.0875 - acc: 0
.9664Epoch 1/100
  1/163 [..............................] - ETA: 55s - loss: 0.1598 - acc:
0.9375
Epoch 00052: saving model to /content/data/model/weights.epoch_52.hdf5
163/163 [==============================] - 88s 542ms/step - loss: 0.0879 -
acc: 0.9663 - val_loss: 0.1598 - val_acc: 0.9375
Epoch 53/100
162/163 [============================>.] - ETA: 0s - loss: 0.0833 - acc: 0
.9688Epoch 1/100
  1/163 [..............................] - ETA: 57s - loss: 0.2053 - acc:
0.8750
Epoch 00053: saving model to /content/data/model/weights.epoch_53.hdf5
163/163 [==============================] - 88s 540ms/step - loss: 0.0832 -
acc: 0.9689 - val_loss: 0.2053 - val_acc: 0.8750
Epoch 54/100
162/163 [============================>.] - ETA: 0s - loss: 0.0880 - acc: 0
.9691Epoch 1/100
  1/163 [..............................] - ETA: 57s - loss: 0.2352 - acc:
0.8750
Epoch 00054: saving model to /content/data/model/weights.epoch_54.hdf5
163/163 [==============================] - 88s 540ms/step - loss: 0.0878 -
acc: 0.9691 - val_loss: 0.2352 - val_acc: 0.8750
Epoch 55/100
162/163 [============================>.] - ETA: 0s - loss: 0.0878 - acc: 0
.9664Epoch 1/100
  1/163 [..............................] - ETA: 59s - loss: 0.1857 - acc:
0.8125
Epoch 00055: saving model to /content/data/model/weights.epoch_55.hdf5
163/163 [==============================] - 88s 541ms/step - loss: 0.0877 -
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acc: 0.9664 - val_loss: 0.1857 - val_acc: 0.8125
Epoch 56/100
162/163 [============================>.] - ETA: 0s - loss: 0.0896 - acc: 0
.9666Epoch 1/100
  1/163 [..............................] - ETA: 56s - loss: 0.1655 - acc:
0.9375
Epoch 00056: saving model to /content/data/model/weights.epoch_56.hdf5
163/163 [==============================] - 88s 539ms/step - loss: 0.0900 -
acc: 0.9664 - val_loss: 0.1655 - val_acc: 0.9375
Epoch 57/100
162/163 [============================>.] - ETA: 0s - loss: 0.0815 - acc: 0
.9734Epoch 1/100
  1/163 [..............................] - ETA: 58s - loss: 0.2047 - acc:
0.8750
Epoch 00057: saving model to /content/data/model/weights.epoch_57.hdf5
163/163 [==============================] - 89s 543ms/step - loss: 0.0819 -
acc: 0.9730 - val_loss: 0.2047 - val_acc: 0.8750
Epoch 58/100
162/163 [============================>.] - ETA: 0s - loss: 0.0831 - acc: 0
.9711Epoch 1/100
  1/163 [..............................] - ETA: 57s - loss: 0.1619 - acc:
0.9375
Epoch 00058: saving model to /content/data/model/weights.epoch_58.hdf5
163/163 [==============================] - 88s 542ms/step - loss: 0.0827 -
acc: 0.9712 - val_loss: 0.1619 - val_acc: 0.9375
Epoch 59/100
162/163 [============================>.] - ETA: 0s - loss: 0.0893 - acc: 0
.9670Epoch 1/100
  1/163 [..............................] - ETA: 57s - loss: 0.2043 - acc:
0.8750
Epoch 00059: saving model to /content/data/model/weights.epoch_59.hdf5
163/163 [==============================] - 89s 544ms/step - loss: 0.0890 -
acc: 0.9672 - val_loss: 0.2043 - val_acc: 0.8750
Epoch 60/100
162/163 [============================>.] - ETA: 0s - loss: 0.0845 - acc: 0
.9703Epoch 1/100
  1/163 [..............................] - ETA: 54s - loss: 0.1591 - acc:
0.9375
Epoch 00060: saving model to /content/data/model/weights.epoch_60.hdf5
163/163 [==============================] - 88s 543ms/step - loss: 0.0841 -
acc: 0.9705 - val_loss: 0.1591 - val_acc: 0.9375
Epoch 61/100
162/163 [============================>.] - ETA: 0s - loss: 0.0831 - acc: 0
.9693Epoch 1/100
  1/163 [..............................] - ETA: 56s - loss: 0.1507 - acc:
1.0000
Epoch 00061: saving model to /content/data/model/weights.epoch_61.hdf5
163/163 [==============================] - 88s 539ms/step - loss: 0.0833 -
acc: 0.9693 - val_loss: 0.1507 - val_acc: 1.0000
Epoch 62/100
162/163 [============================>.] - ETA: 0s - loss: 0.0841 - acc: 0
.9682Epoch 1/100
  1/163 [..............................] - ETA: 58s - loss: 0.1635 - acc:
1.0000
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Epoch 00062: saving model to /content/data/model/weights.epoch_62.hdf5
163/163 [==============================] - 88s 541ms/step - loss: 0.0839 -
acc: 0.9682 - val_loss: 0.1635 - val_acc: 1.0000
Epoch 63/100
162/163 [============================>.] - ETA: 0s - loss: 0.0807 - acc: 0
.9705Epoch 1/100
  1/163 [..............................] - ETA: 56s - loss: 0.1537 - acc:
1.0000
Epoch 00063: saving model to /content/data/model/weights.epoch_63.hdf5
163/163 [==============================] - 87s 533ms/step - loss: 0.0802 -
acc: 0.9707 - val_loss: 0.1537 - val_acc: 1.0000
Epoch 64/100
162/163 [============================>.] - ETA: 0s - loss: 0.0805 - acc: 0
.9713Epoch 1/100
  1/163 [..............................] - ETA: 56s - loss: 0.1437 - acc:
0.9375
Epoch 00064: saving model to /content/data/model/weights.epoch_64.hdf5
163/163 [==============================] - 86s 527ms/step - loss: 0.0813 -
acc: 0.9711 - val_loss: 0.1437 - val_acc: 0.9375
Epoch 65/100
162/163 [============================>.] - ETA: 0s - loss: 0.0826 - acc: 0
.9707Epoch 1/100
  1/163 [..............................] - ETA: 55s - loss: 0.1765 - acc:
0.9375
Epoch 00065: saving model to /content/data/model/weights.epoch_65.hdf5
163/163 [==============================] - 88s 538ms/step - loss: 0.0824 -
acc: 0.9707 - val_loss: 0.1765 - val_acc: 0.9375
Epoch 66/100
162/163 [============================>.] - ETA: 0s - loss: 0.0794 - acc: 0
.9697Epoch 1/100
  1/163 [..............................] - ETA: 54s - loss: 0.1714 - acc:
0.9375
Epoch 00066: saving model to /content/data/model/weights.epoch_66.hdf5
163/163 [==============================] - 88s 541ms/step - loss: 0.0797 -
acc: 0.9697 - val_loss: 0.1714 - val_acc: 0.9375
Epoch 67/100
162/163 [============================>.] - ETA: 0s - loss: 0.0801 - acc: 0
.9707Epoch 1/100
  1/163 [..............................] - ETA: 1:01 - loss: 0.1510 - acc:
0.9375
Epoch 00067: saving model to /content/data/model/weights.epoch_67.hdf5
163/163 [==============================] - 88s 540ms/step - loss: 0.0804 -
acc: 0.9705 - val_loss: 0.1510 - val_acc: 0.9375
Epoch 68/100
162/163 [============================>.] - ETA: 0s - loss: 0.0768 - acc: 0
.9734Epoch 1/100
  1/163 [..............................] - ETA: 55s - loss: 0.1502 - acc:
0.9375
Epoch 00068: saving model to /content/data/model/weights.epoch_68.hdf5
163/163 [==============================] - 88s 539ms/step - loss: 0.0768 -
acc: 0.9732 - val_loss: 0.1502 - val_acc: 0.9375
Epoch 69/100
162/163 [============================>.] - ETA: 0s - loss: 0.0859 - acc: 0
.9682Epoch 1/100
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  1/163 [..............................] - ETA: 55s - loss: 0.1616 - acc:
1.0000
Epoch 00069: saving model to /content/data/model/weights.epoch_69.hdf5
163/163 [==============================] - 88s 539ms/step - loss: 0.0855 -
acc: 0.9684 - val_loss: 0.1616 - val_acc: 1.0000
Epoch 70/100
162/163 [============================>.] - ETA: 0s - loss: 0.0780 - acc: 0
.9709Epoch 1/100
  1/163 [..............................] - ETA: 54s - loss: 0.1661 - acc:
1.0000
Epoch 00070: saving model to /content/data/model/weights.epoch_70.hdf5
163/163 [==============================] - 89s 544ms/step - loss: 0.0779 -
acc: 0.9709 - val_loss: 0.1661 - val_acc: 1.0000
Epoch 71/100
162/163 [============================>.] - ETA: 0s - loss: 0.0783 - acc: 0
.9718Epoch 1/100
  1/163 [..............................] - ETA: 57s - loss: 0.1486 - acc:
1.0000
Epoch 00071: saving model to /content/data/model/weights.epoch_71.hdf5
163/163 [==============================] - 88s 538ms/step - loss: 0.0803 -
acc: 0.9712 - val_loss: 0.1486 - val_acc: 1.0000
Epoch 72/100
162/163 [============================>.] - ETA: 0s - loss: 0.0803 - acc: 0
.9707Epoch 1/100
  1/163 [..............................] - ETA: 56s - loss: 0.1702 - acc:
0.8750
Epoch 00072: saving model to /content/data/model/weights.epoch_72.hdf5
163/163 [==============================] - 88s 539ms/step - loss: 0.0802 -
acc: 0.9707 - val_loss: 0.1702 - val_acc: 0.8750
Epoch 73/100
162/163 [============================>.] - ETA: 0s - loss: 0.0807 - acc: 0
.9709Epoch 1/100
  1/163 [..............................] - ETA: 57s - loss: 0.1317 - acc:
0.9375
Epoch 00073: saving model to /content/data/model/weights.epoch_73.hdf5
163/163 [==============================] - 89s 543ms/step - loss: 0.0804 -
acc: 0.9711 - val_loss: 0.1317 - val_acc: 0.9375
Epoch 74/100
162/163 [============================>.] - ETA: 0s - loss: 0.0781 - acc: 0
.9726Epoch 1/100
  1/163 [..............................] - ETA: 57s - loss: 0.1768 - acc:
0.8750
Epoch 00074: saving model to /content/data/model/weights.epoch_74.hdf5
163/163 [==============================] - 88s 540ms/step - loss: 0.0782 -
acc: 0.9724 - val_loss: 0.1768 - val_acc: 0.8750
Epoch 75/100
162/163 [============================>.] - ETA: 0s - loss: 0.0805 - acc: 0
.9711Epoch 1/100
  1/163 [..............................] - ETA: 56s - loss: 0.1339 - acc:
0.9375
Epoch 00075: saving model to /content/data/model/weights.epoch_75.hdf5
163/163 [==============================] - 88s 538ms/step - loss: 0.0810 -
acc: 0.9709 - val_loss: 0.1339 - val_acc: 0.9375
Epoch 76/100
```

```
162/163 [============================>.] - ETA: 0s - loss: 0.0808 - acc: 0
.9684Epoch 1/100
  1/163 [..............................] - ETA: 55s - loss: 0.1425 - acc:
0.9375
Epoch 00076: saving model to /content/data/model/weights.epoch_76.hdf5
163/163 [==============================] - 88s 540ms/step - loss: 0.0821 -
acc: 0.9680 - val_loss: 0.1425 - val_acc: 0.9375
Epoch 77/100
162/163 [============================>.] - ETA: 0s - loss: 0.0756 - acc: 0
.9732Epoch 1/100
  1/163 [..............................] - ETA: 54s - loss: 0.1535 - acc:
1.0000
Epoch 00077: saving model to /content/data/model/weights.epoch_77.hdf5
163/163 [==============================] - 88s 541ms/step - loss: 0.0758 -
acc: 0.9728 - val_loss: 0.1535 - val_acc: 1.0000
Epoch 78/100
162/163 [============================>.] - ETA: 0s - loss: 0.0798 - acc: 0
.9715Epoch 1/100
  1/163 [..............................] - ETA: 53s - loss: 0.1461 - acc:
0.9375
Epoch 00078: saving model to /content/data/model/weights.epoch_78.hdf5
163/163 [==============================] - 88s 539ms/step - loss: 0.0796 -
acc: 0.9716 - val_loss: 0.1461 - val_acc: 0.9375
Epoch 79/100
162/163 [============================>.] - ETA: 0s - loss: 0.0758 - acc: 0
.9705Epoch 1/100
  1/163 [..............................] - ETA: 57s - loss: 0.1623 - acc:
1.0000
Epoch 00079: saving model to /content/data/model/weights.epoch_79.hdf5
163/163 [==============================] - 87s 534ms/step - loss: 0.0760 -
acc: 0.9705 - val_loss: 0.1623 - val_acc: 1.0000
Epoch 80/100
162/163 [============================>.] - ETA: 0s - loss: 0.0751 - acc: 0
.9726Epoch 1/100
  1/163 [..............................] - ETA: 56s - loss: 0.1533 - acc:
0.9375
Epoch 00080: saving model to /content/data/model/weights.epoch_80.hdf5
163/163 [==============================] - 87s 537ms/step - loss: 0.0749 -
acc: 0.9728 - val_loss: 0.1533 - val_acc: 0.9375
Epoch 81/100
162/163 [============================>.] - ETA: 0s - loss: 0.0799 - acc: 0
.9707Epoch 1/100
  1/163 [..............................] - ETA: 56s - loss: 0.1477 - acc:
1.0000
Epoch 00081: saving model to /content/data/model/weights.epoch_81.hdf5
163/163 [==============================] - 88s 539ms/step - loss: 0.0796 -
acc: 0.9709 - val_loss: 0.1477 - val_acc: 1.0000
Epoch 82/100
162/163 [============================>.] - ETA: 0s - loss: 0.0755 - acc: 0
.9747Epoch 1/100
  1/163 [..............................] - ETA: 56s - loss: 0.1323 - acc:
0.9375
Epoch 00082: saving model to /content/data/model/weights.epoch_82.hdf5
163/163 [==============================] - 87s 535ms/step - loss: 0.0753 -
```

```
acc: 0.9747 - val_loss: 0.1323 - val_acc: 0.9375
Epoch 83/100
162/163 [============================>.] - ETA: 0s - loss: 0.0730 - acc: 0
.9728Epoch 1/100
  1/163 [..............................] - ETA: 58s - loss: 0.1315 - acc:
0.9375
Epoch 00083: saving model to /content/data/model/weights.epoch_83.hdf5
163/163 [==============================] - 88s 537ms/step - loss: 0.0728 -
acc: 0.9730 - val_loss: 0.1315 - val_acc: 0.9375
Epoch 84/100
162/163 [============================>.] - ETA: 0s - loss: 0.0695 - acc: 0
.9732Epoch 1/100
  1/163 [..............................] - ETA: 57s - loss: 0.1608 - acc:
0.9375
Epoch 00084: saving model to /content/data/model/weights.epoch_84.hdf5
163/163 [==============================] - 87s 535ms/step - loss: 0.0695 -
acc: 0.9732 - val_loss: 0.1608 - val_acc: 0.9375
Epoch 85/100
162/163 [============================>.] - ETA: 0s - loss: 0.0805 - acc: 0
.9703Epoch 1/100
  1/163 [..............................] - ETA: 56s - loss: 0.1449 - acc:
0.9375
Epoch 00085: saving model to /content/data/model/weights.epoch_85.hdf5
163/163 [==============================] - 87s 535ms/step - loss: 0.0808 -
acc: 0.9701 - val_loss: 0.1449 - val_acc: 0.9375
Epoch 86/100
162/163 [============================>.] - ETA: 0s - loss: 0.0748 - acc: 0
.9736Epoch 1/100
  1/163 [..............................] - ETA: 57s - loss: 0.1439 - acc:
0.9375
Epoch 00086: saving model to /content/data/model/weights.epoch_86.hdf5
163/163 [==============================] - 87s 536ms/step - loss: 0.0747 -
acc: 0.9735 - val_loss: 0.1439 - val_acc: 0.9375
Epoch 87/100
162/163 [============================>.] - ETA: 0s - loss: 0.0728 - acc: 0
.9718Epoch 1/100
  1/163 [..............................] - ETA: 51s - loss: 0.1476 - acc:
1.0000
Epoch 00087: saving model to /content/data/model/weights.epoch_87.hdf5
163/163 [==============================] - 87s 534ms/step - loss: 0.0727 -
acc: 0.9718 - val_loss: 0.1476 - val_acc: 1.0000
Epoch 88/100
162/163 [============================>.] - ETA: 0s - loss: 0.0773 - acc: 0
.9722Epoch 1/100
  1/163 [..............................] - ETA: 54s - loss: 0.1540 - acc:
1.0000
Epoch 00088: saving model to /content/data/model/weights.epoch_88.hdf5
163/163 [==============================] - 84s 516ms/step - loss: 0.0774 -
acc: 0.9722 - val_loss: 0.1540 - val_acc: 1.0000
Epoch 89/100
162/163 [============================>.] - ETA: 0s - loss: 0.0775 - acc: 0
.9711Epoch 1/100
  1/163 [..............................] - ETA: 52s - loss: 0.1274 - acc:
0.9375
```

```
Epoch 00089: saving model to /content/data/model/weights.epoch_89.hdf5
163/163 [==============================] - 84s 513ms/step - loss: 0.0776 -
acc: 0.9709 - val_loss: 0.1274 - val_acc: 0.9375
Epoch 90/100
162/163 [============================>.] - ETA: 0s - loss: 0.0744 - acc: 0
.9720Epoch 1/100
  1/163 [..............................] - ETA: 51s - loss: 0.1485 - acc:
1.0000
Epoch 00090: saving model to /content/data/model/weights.epoch_90.hdf5
163/163 [==============================] - 83s 509ms/step - loss: 0.0748 -
acc: 0.9720 - val_loss: 0.1485 - val_acc: 1.0000
Epoch 91/100
162/163 [============================>.] - ETA: 0s - loss: 0.0737 - acc: 0
.9757Epoch 1/100
  1/163 [..............................] - ETA: 52s - loss: 0.1356 - acc:
0.9375
Epoch 00091: saving model to /content/data/model/weights.epoch_91.hdf5
163/163 [==============================] - 83s 511ms/step - loss: 0.0738 -
acc: 0.9755 - val_loss: 0.1356 - val_acc: 0.9375
Epoch 92/100
162/163 [============================>.] - ETA: 0s - loss: 0.0773 - acc: 0
.9724Epoch 1/100
  1/163 [..............................] - ETA: 55s - loss: 0.1256 - acc:
0.9375
Epoch 00092: saving model to /content/data/model/weights.epoch_92.hdf5
163/163 [==============================] - 83s 507ms/step - loss: 0.0771 -
acc: 0.9726 - val_loss: 0.1256 - val_acc: 0.9375
Epoch 93/100
162/163 [============================>.] - ETA: 0s - loss: 0.0770 - acc: 0
.9728Epoch 1/100
  1/163 [..............................] - ETA: 54s - loss: 0.1291 - acc:
0.9375
Epoch 00093: saving model to /content/data/model/weights.epoch_93.hdf5
163/163 [==============================] - 82s 501ms/step - loss: 0.0769 -
acc: 0.9728 - val_loss: 0.1291 - val_acc: 0.9375
Epoch 94/100
162/163 [============================>.] - ETA: 0s - loss: 0.0738 - acc: 0
.9699Epoch 1/100
  1/163 [..............................] - ETA: 53s - loss: 0.1270 - acc:
0.9375
Epoch 00094: saving model to /content/data/model/weights.epoch_94.hdf5
163/163 [==============================] - 83s 507ms/step - loss: 0.0737 -
acc: 0.9699 - val_loss: 0.1270 - val_acc: 0.9375
Epoch 95/100
162/163 [============================>.] - ETA: 0s - loss: 0.0780 - acc: 0
.9713Epoch 1/100
  1/163 [..............................] - ETA: 53s - loss: 0.1212 - acc:
0.9375
Epoch 00095: saving model to /content/data/model/weights.epoch_95.hdf5
163/163 [==============================] - 83s 507ms/step - loss: 0.0783 -
acc: 0.9709 - val_loss: 0.1212 - val_acc: 0.9375
Epoch 96/100
162/163 [============================>.] - ETA: 0s - loss: 0.0724 - acc: 0
.9745Epoch 1/100
```

```
  1/163 [..............................] - ETA: 55s - loss: 0.1220 - acc:
0.9375
Epoch 00096: saving model to /content/data/model/weights.epoch_96.hdf5
163/163 [==============================] - 84s 516ms/step - loss: 0.0726 -
acc: 0.9745 - val_loss: 0.1220 - val_acc: 0.9375
Epoch 97/100
162/163 [============================>.] - ETA: 0s - loss: 0.0736 - acc: 0
.9720Epoch 1/100
  1/163 [..............................] - ETA: 54s - loss: 0.1406 - acc:
1.0000
Epoch 00097: saving model to /content/data/model/weights.epoch_97.hdf5
163/163 [==============================] - 84s 514ms/step - loss: 0.0736 -
acc: 0.9720 - val_loss: 0.1406 - val_acc: 1.0000
Epoch 98/100
162/163 [============================>.] - ETA: 0s - loss: 0.0688 - acc: 0
.9763Epoch 1/100
  1/163 [..............................] - ETA: 54s - loss: 0.1175 - acc:
0.9375
Epoch 00098: saving model to /content/data/model/weights.epoch_98.hdf5
163/163 [==============================] - 85s 520ms/step - loss: 0.0688 -
acc: 0.9762 - val_loss: 0.1175 - val_acc: 0.9375
Epoch 99/100
162/163 [============================>.] - ETA: 0s - loss: 0.0705 - acc: 0
.9724Epoch 1/100
  1/163 [..............................] - ETA: 55s - loss: 0.1362 - acc:
1.0000
Epoch 00099: saving model to /content/data/model/weights.epoch_99.hdf5
163/163 [==============================] - 86s 525ms/step - loss: 0.0705 -
acc: 0.9724 - val_loss: 0.1362 - val_acc: 1.0000
Epoch 100/100
162/163 [============================>.] - ETA: 0s - loss: 0.0725 - acc: 0
.9738Epoch 1/100
  1/163 [..............................] - ETA: 51s - loss: 0.1209 - acc:
0.9375
Epoch 00100: saving model to /content/data/model/weights.epoch_100.hdf5
163/163 [==============================] - 85s 523ms/step - loss: 0.0722 -
acc: 0.9739 - val_loss: 0.1209 - val_acc: 0.9375
```

```
import matplotlib.pyplot as plt
def plot_learning_curves(history):
    plt.figure(figsize=(12,4))

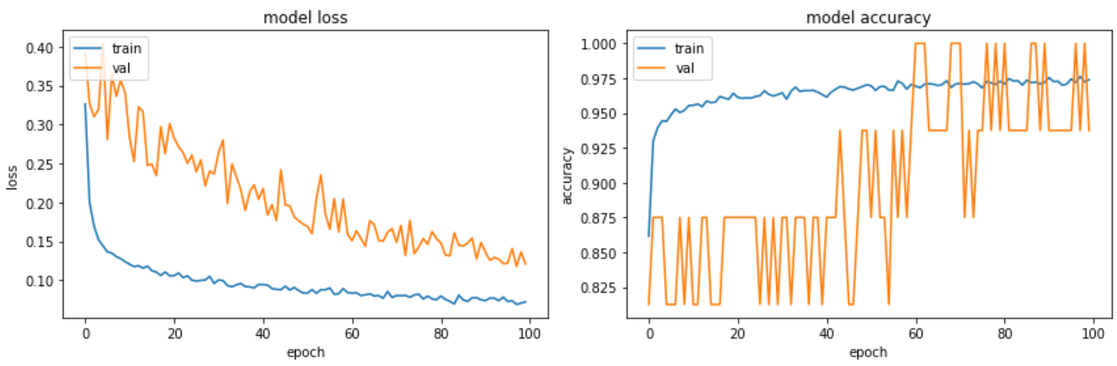
    plt.subplot(1,2,1)
    plt.plot(history.history['loss'])
    plt.plot(history.history['val_loss'])
    plt.title('model loss')
    plt.ylabel('loss')
    plt.xlabel('epoch')
    plt.legend(['train', 'val'], loc='upper left')

    plt.subplot(1,2,2)
    plt.plot(history.history['acc'])
    plt.plot(history.history['val_acc'])
    plt.title('model accuracy')
```

```
    plt.ylabel('accuracy')
    plt.xlabel('epoch')
    plt.legend(['train', 'val'], loc='upper left')

    plt.tight_layout()

plot_learning_curves(history)
```



png

```
idx = np.argmin(history.history['val_loss'])
model.load_weights("/content/data/model/weights.epoch_{:02d}.hdf5".format(
idx + 1))

print("Loading the best model")
print("epoch: {}, val_loss: {}, val_acc: {}".format(idx + 1, history.histo
ry['val_loss'][idx], history.history['val_acc'][idx]))
```

```
Loading the best model
epoch: 98, val_loss: 0.11746180802583694, val_acc: 0.9375
```

```
test_loss, test_acc = model.evaluate_generator(generator=test_generator, v
erbose=1)
```

```
20/20 [==============================] - 6s 318ms/step - loss: 0.2124 - ac
c: 0.9263
```

```
from sklearn.metrics import accuracy_score, confusion_matrix

test_generator.reset()
test_preds = model.predict_generator(test_generator, verbose=1)
test_preds = np.argmax(test_preds,axis=1)

acc = accuracy_score(test_generator.classes, test_preds)*100
cm = confusion_matrix(test_generator.classes, test_preds)
tn, fp, fn, tp = cm.ravel()

print('CONFUSION MATRIX ------------------')
print(cm)
# plot_confusion_matrix(cm, target_names=['NORMAL', 'PNEUMONIA'], normaliz
e=False)


print('\nTEST METRICS ----------------------')
```

```
precision = tp/(tp+fp)*100
recall = tp/(tp+fn)*100
print('Accuracy: {}%'.format(acc))
print('Precision: {}%'.format(precision))
print('Recall: {}%'.format(recall))
print('F1-score: {}'.format(2*precision*recall/(precision+recall)))

print('\nTRAIN METRIC ----------------------')
print('Train acc: {}%'.format(np.round((history.history['acc'][-1])*100, 1
4)))
```

```
20/20 [==============================] - 7s 344ms/step
CONFUSION MATRIX ------------------
[[204  30]
 [ 16 374]]

TEST METRICS ----------------------
Accuracy: 92.62820512820514%
Precision: 92.57425742574257%
Recall: 95.8974358974359%
F1-score: 94.20654911838791

TRAIN METRIC ----------------------
Train acc: 97.39263653755188%
```

9.5 Appendix E: VGG16 Model 1 Version 1.1.1.1.0

```
from __future__ import absolute_import, division, print_function, unicode_
literals
import tensorflow as tf

# Extract dataset
import os
import tarfile

import keras_preprocessing
from keras_preprocessing.image import ImageDataGenerator # Data preprocess
ing and augmentation

import sklearn
import numpy as np
```

The default version of TensorFlow in Colab will soon switch to TensorFlow 2.x. We recommend you upgrade now or ensure your notebook will continue to use TensorFlow 1.x via the %tensorflow_version 1.x magic: more info.

```
print(tf.__version__)
```

```
1.15.0
```

```
# Make folder for chest xray data
!mkdir /content/data/

# Make directory to save weights
!mkdir /content/data/model

# Make directory to logs for Tensorboard
!mkdir /content/data/graph

# Download dataset
!wget --no-check-certificate \
    https://s3.eu-central-1.amazonaws.com/public.unit8.co/data/chest_xray.
tar.gz \
    -O /content/data/chest_xray.tar.gz

tar = tarfile.open("data/chest_xray.tar.gz")
tar.extractall(path='./data/')
os.remove('data/chest_xray.tar.gz')
```

```
--2019-10-28 10:21:03--  https://s3.eu-central-1.amazonaws.com/public.unit
8.co/data/chest_xray.tar.gz
Resolving s3.eu-central-1.amazonaws.com (s3.eu-central-1.amazonaws.com)...
52.219.73.139
Connecting to s3.eu-central-1.amazonaws.com (s3.eu-central-1.amazonaws.com
)|52.219.73.139|:443... connected.
HTTP request sent, awaiting response... 200 OK
Length: 1225393795 (1.1G) [application/x-gzip]
Saving to: ‘/content/data/chest_xray.tar.gz’
```

```
/content/data/chest 100%[===================>]   1.14G  11.8MB/s    in 1m
42s

2019-10-28 10:22:46 (11.4 MB/s) - ‘/content/data/chest_xray.tar.gz’ saved
[1225393795/1225393795]
```

Change log: > training_datagen –> ImageDataGenerator

trainable layer –> All except base

20 layers VGG16 model - base, flat, dense

Optimizer = RMSprop(learning_rate = 0.0001)

loss = categorical_crosscentropy

callback = [checkpoints]

epochs = 100

class weight balancing

```
TRAINING_DIR = "/content/data/chest_xray/train"
VALIDATION_DIR = "/content/data/chest_xray/val"
TEST_DIR = "/content/data/chest_xray/test"

training_datagen = ImageDataGenerator(
    preprocessing_function=tf.keras.applications.vgg16.preprocess_input,
    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,
    # vertical_flip=True
    fill_mode='nearest'
)

validation_datagen = ImageDataGenerator(
    rescale = 1./255
)

test_datagen = ImageDataGenerator(
    rescale = 1./255
)

# Create training data batch
# TODO: Try grayscaling the image to see what will happen
train_generator = training_datagen.flow_from_directory(
    TRAINING_DIR,
    target_size=(150,150),
    class_mode='categorical'
)

validation_generator = validation_datagen.flow_from_directory(
    VALIDATION_DIR,
```

```
    target_size=(150,150),
    class_mode='categorical'
)

test_generator = test_datagen.flow_from_directory(
    TEST_DIR,
    target_size=(150,150),
    class_mode='categorical',
    shuffle=False
)

train_shape = train_generator.image_shape

tf.keras.backend.clear_session() # Destroys the current TF graph and creat
es a new one.

base_model = tf.keras.applications.VGG16(weights='imagenet', include_top=F
alse, input_shape=train_shape)

# Define the machine learning model
x = base_model.output
x = tf.keras.layers.Flatten()(x)
x = tf.keras.layers.Dense(2, 'softmax')(x)

model = tf.keras.Model(inputs=base_model.input, outputs=x)

# for layer in model.layers[0:20]:
#     layer.trainable = False

for layer in base_model.layers:
  layer.trainable = False

optimizer = tf.keras.optimizers.RMSprop(learning_rate=0.0001) # Lower lear
ning rate by x10

model.compile(loss='categorical_crossentropy',
              optimizer=optimizer,
              metrics=['accuracy'])

# Callbacks stuff
# Function to save the weights of the model after each epoch
checkpoint = tf.keras.callbacks.ModelCheckpoint(
    '/content/data/model/weights.epoch_{epoch:02d}.hdf5',
    monitor='val_accuracy',
    save_best_only=False,
    save_weights_only=False,
    mode='auto',
    verbose=1
)

# Function to stop training early if there's no improvement
early_stopping_monitor = tf.keras.callbacks.EarlyStopping(patience = 3, mo
nitor = "val_loss", mode="auto", verbose = 1)
```

```
lr_reduce = tf.keras.callbacks.ReduceLROnPlateau(monitor='val_loss', facto
r=0.3, patience=2, verbose=1, mode='max')

classweight = sklearn.utils.class_weight.compute_class_weight('balanced',
np.unique(train_generator.labels), train_generator.labels)
print(classweight)

# batch_size = 32
epochs = 100

# Training process
history = model.fit_generator(
    generator=train_generator,
    # steps_per_epoch=train_generator.samples//batch_size,
    epochs=epochs,
    # callbacks=[early_stopping_monitor],
    callbacks=[checkpoint],
    # shuffle=True,
    validation_data=validation_generator,
    # validation_steps= validation_generator//batch_size, #no because it's
gonna be 0... if leave alone its len(generator) which is equal to 1.
    class_weight=classweight,
    verbose = 1
)

# test_loss, test_acc = model.evaluate_generator(generator=test_generator,
verbose=1)
```

```
Found 5216 images belonging to 2 classes.
Found 16 images belonging to 2 classes.
Found 624 images belonging to 2 classes.
WARNING:tensorflow:From /usr/local/lib/python3.6/dist-packages/tensorflow_
core/python/ops/resource_variable_ops.py:1630: calling BaseResourceVariabl
e.__init__ (from tensorflow.python.ops.resource_variable_ops) with constra
int is deprecated and will be removed in a future version.
Instructions for updating:
If using Keras pass *_constraint arguments to layers.
[1.9448173  0.67303226]
Epoch 1/100
162/163 [============================>.] - ETA: 0s - loss: 0.3773 - acc: 0
.8306Epoch 1/100
  1/163 [..............................] - ETA: 4:21 - loss: 0.5004 - acc:
0.6875
Epoch 00001: saving model to /content/data/model/weights.epoch_01.hdf5
163/163 [==============================] - 89s 546ms/step - loss: 0.3766 -
acc: 0.8305 - val_loss: 0.5004 - val_acc: 0.6875
Epoch 2/100
162/163 [============================>.] - ETA: 0s - loss: 0.2072 - acc: 0
.9246Epoch 1/100
  1/163 [..............................] - ETA: 55s - loss: 0.4754 - acc:
0.8125
Epoch 00002: saving model to /content/data/model/weights.epoch_02.hdf5
163/163 [==============================] - 86s 526ms/step - loss: 0.2069 -
acc: 0.9247 - val_loss: 0.4754 - val_acc: 0.8125
```

```
Epoch 3/100
162/163 [============================>.] - ETA: 0s - loss: 0.1681 - acc: 0
.9394Epoch 1/100
  1/163 [..............................] - ETA: 55s - loss: 0.3732 - acc:
0.8125
Epoch 00003: saving model to /content/data/model/weights.epoch_03.hdf5
163/163 [==============================] - 86s 530ms/step - loss: 0.1684 -
acc: 0.9392 - val_loss: 0.3732 - val_acc: 0.8125
Epoch 4/100
162/163 [============================>.] - ETA: 0s - loss: 0.1580 - acc: 0
.9410Epoch 1/100
  1/163 [..............................] - ETA: 56s - loss: 0.3762 - acc:
0.8125
Epoch 00004: saving model to /content/data/model/weights.epoch_04.hdf5
163/163 [==============================] - 87s 536ms/step - loss: 0.1584 -
acc: 0.9408 - val_loss: 0.3762 - val_acc: 0.8125
Epoch 5/100
162/163 [============================>.] - ETA: 0s - loss: 0.1480 - acc: 0
.9446Epoch 1/100
  1/163 [..............................] - ETA: 56s - loss: 0.3562 - acc:
0.8750
Epoch 00005: saving model to /content/data/model/weights.epoch_05.hdf5
163/163 [==============================] - 88s 538ms/step - loss: 0.1483 -
acc: 0.9444 - val_loss: 0.3562 - val_acc: 0.8750
Epoch 6/100
162/163 [============================>.] - ETA: 0s - loss: 0.1468 - acc: 0
.9456Epoch 1/100
  1/163 [..............................] - ETA: 57s - loss: 0.3326 - acc:
0.8750
Epoch 00006: saving model to /content/data/model/weights.epoch_06.hdf5
163/163 [==============================] - 88s 539ms/step - loss: 0.1462 -
acc: 0.9459 - val_loss: 0.3326 - val_acc: 0.8750
Epoch 7/100
162/163 [============================>.] - ETA: 0s - loss: 0.1376 - acc: 0
.9512Epoch 1/100
  1/163 [..............................] - ETA: 58s - loss: 0.3545 - acc:
0.8750
Epoch 00007: saving model to /content/data/model/weights.epoch_07.hdf5
163/163 [==============================] - 88s 538ms/step - loss: 0.1376 -
acc: 0.9511 - val_loss: 0.3545 - val_acc: 0.8750
Epoch 8/100
162/163 [============================>.] - ETA: 0s - loss: 0.1325 - acc: 0
.9522Epoch 1/100
  1/163 [..............................] - ETA: 56s - loss: 0.3730 - acc:
0.8125
Epoch 00008: saving model to /content/data/model/weights.epoch_08.hdf5
163/163 [==============================] - 88s 538ms/step - loss: 0.1321 -
acc: 0.9525 - val_loss: 0.3730 - val_acc: 0.8125
Epoch 9/100
162/163 [============================>.] - ETA: 0s - loss: 0.1300 - acc: 0
.9533Epoch 1/100
  1/163 [..............................] - ETA: 57s - loss: 0.3236 - acc:
0.8125
Epoch 00009: saving model to /content/data/model/weights.epoch_09.hdf5
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163/163 [==============================] - 87s 533ms/step - loss: 0.1305 -
acc: 0.9532 - val_loss: 0.3236 - val_acc: 0.8125
Epoch 10/100
162/163 [============================>.] - ETA: 0s - loss: 0.1187 - acc: 0
.9554Epoch 1/100
  1/163 [..............................] - ETA: 58s - loss: 0.2798 - acc:
0.8125
Epoch 00010: saving model to /content/data/model/weights.epoch_10.hdf5
163/163 [==============================] - 88s 537ms/step - loss: 0.1199 -
acc: 0.9549 - val_loss: 0.2798 - val_acc: 0.8125
Epoch 11/100
162/163 [============================>.] - ETA: 0s - loss: 0.1187 - acc: 0
.9564Epoch 1/100
  1/163 [..............................] - ETA: 54s - loss: 0.3215 - acc:
0.8750
Epoch 00011: saving model to /content/data/model/weights.epoch_11.hdf5
163/163 [==============================] - 87s 537ms/step - loss: 0.1184 -
acc: 0.9567 - val_loss: 0.3215 - val_acc: 0.8750
Epoch 12/100
162/163 [============================>.] - ETA: 0s - loss: 0.1238 - acc: 0
.9525Epoch 1/100
  1/163 [..............................] - ETA: 54s - loss: 0.2829 - acc:
0.8125
Epoch 00012: saving model to /content/data/model/weights.epoch_12.hdf5
163/163 [==============================] - 88s 538ms/step - loss: 0.1236 -
acc: 0.9528 - val_loss: 0.2829 - val_acc: 0.8125
Epoch 13/100
162/163 [============================>.] - ETA: 0s - loss: 0.1208 - acc: 0
.9535Epoch 1/100
  1/163 [..............................] - ETA: 55s - loss: 0.3452 - acc:
0.8750
Epoch 00013: saving model to /content/data/model/weights.epoch_13.hdf5
163/163 [==============================] - 87s 535ms/step - loss: 0.1208 -
acc: 0.9534 - val_loss: 0.3452 - val_acc: 0.8750
Epoch 14/100
162/163 [============================>.] - ETA: 0s - loss: 0.1176 - acc: 0
.9562Epoch 1/100
  1/163 [..............................] - ETA: 57s - loss: 0.3922 - acc:
0.7500
Epoch 00014: saving model to /content/data/model/weights.epoch_14.hdf5
163/163 [==============================] - 88s 538ms/step - loss: 0.1174 -
acc: 0.9565 - val_loss: 0.3922 - val_acc: 0.7500
Epoch 15/100
162/163 [============================>.] - ETA: 0s - loss: 0.1129 - acc: 0
.9593Epoch 1/100
  1/163 [..............................] - ETA: 56s - loss: 0.2431 - acc:
0.8125
Epoch 00015: saving model to /content/data/model/weights.epoch_15.hdf5
163/163 [==============================] - 88s 538ms/step - loss: 0.1126 -
acc: 0.9594 - val_loss: 0.2431 - val_acc: 0.8125
Epoch 16/100
162/163 [============================>.] - ETA: 0s - loss: 0.1140 - acc: 0
.9583Epoch 1/100
  1/163 [..............................] - ETA: 58s - loss: 0.3275 - acc:
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0.8750
Epoch 00016: saving model to /content/data/model/weights.epoch_16.hdf5
163/163 [==============================] - 87s 534ms/step - loss: 0.1136 -
acc: 0.9584 - val_loss: 0.3275 - val_acc: 0.8750
Epoch 17/100
162/163 [============================>.] - ETA: 0s - loss: 0.1116 - acc: 0
.9618Epoch 1/100
  1/163 [..............................] - ETA: 54s - loss: 0.3228 - acc:
0.8750
Epoch 00017: saving model to /content/data/model/weights.epoch_17.hdf5
163/163 [==============================] - 87s 532ms/step - loss: 0.1116 -
acc: 0.9618 - val_loss: 0.3228 - val_acc: 0.8750
Epoch 18/100
162/163 [============================>.] - ETA: 0s - loss: 0.1108 - acc: 0
.9610Epoch 1/100
  1/163 [..............................] - ETA: 53s - loss: 0.2198 - acc:
0.8125
Epoch 00018: saving model to /content/data/model/weights.epoch_18.hdf5
163/163 [==============================] - 86s 529ms/step - loss: 0.1108 -
acc: 0.9611 - val_loss: 0.2198 - val_acc: 0.8125
Epoch 19/100
162/163 [============================>.] - ETA: 0s - loss: 0.1038 - acc: 0
.9635Epoch 1/100
  1/163 [..............................] - ETA: 53s - loss: 0.2708 - acc:
0.8125
Epoch 00019: saving model to /content/data/model/weights.epoch_19.hdf5
163/163 [==============================] - 86s 529ms/step - loss: 0.1041 -
acc: 0.9634 - val_loss: 0.2708 - val_acc: 0.8125
Epoch 20/100
162/163 [============================>.] - ETA: 0s - loss: 0.1104 - acc: 0
.9605Epoch 1/100
  1/163 [..............................] - ETA: 55s - loss: 0.2999 - acc:
0.8750
Epoch 00020: saving model to /content/data/model/weights.epoch_20.hdf5
163/163 [==============================] - 86s 527ms/step - loss: 0.1105 -
acc: 0.9603 - val_loss: 0.2999 - val_acc: 0.8750
Epoch 21/100
162/163 [============================>.] - ETA: 0s - loss: 0.1073 - acc: 0
.9608Epoch 1/100
  1/163 [..............................] - ETA: 54s - loss: 0.2911 - acc:
0.8750
Epoch 00021: saving model to /content/data/model/weights.epoch_21.hdf5
163/163 [==============================] - 87s 533ms/step - loss: 0.1069 -
acc: 0.9611 - val_loss: 0.2911 - val_acc: 0.8750
Epoch 22/100
162/163 [============================>.] - ETA: 0s - loss: 0.1044 - acc: 0
.9608Epoch 1/100
  1/163 [..............................] - ETA: 53s - loss: 0.2555 - acc:
0.8125
Epoch 00022: saving model to /content/data/model/weights.epoch_22.hdf5
163/163 [==============================] - 87s 535ms/step - loss: 0.1051 -
acc: 0.9607 - val_loss: 0.2555 - val_acc: 0.8125
Epoch 23/100
162/163 [============================>.] - ETA: 0s - loss: 0.1032 - acc: 0
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.9643Epoch 1/100
  1/163 [..............................] - ETA: 58s - loss: 0.2417 - acc:
0.8125
Epoch 00023: saving model to /content/data/model/weights.epoch_23.hdf5
163/163 [==============================] - 87s 533ms/step - loss: 0.1036 -
acc: 0.9643 - val_loss: 0.2417 - val_acc: 0.8125
Epoch 24/100
162/163 [============================>.] - ETA: 0s - loss: 0.1002 - acc: 0
.9643Epoch 1/100
  1/163 [..............................] - ETA: 56s - loss: 0.2176 - acc:
0.8125
Epoch 00024: saving model to /content/data/model/weights.epoch_24.hdf5
163/163 [==============================] - 87s 534ms/step - loss: 0.1001 -
acc: 0.9643 - val_loss: 0.2176 - val_acc: 0.8125
Epoch 25/100
162/163 [============================>.] - ETA: 0s - loss: 0.1023 - acc: 0
.9632Epoch 1/100
  1/163 [..............................] - ETA: 55s - loss: 0.2242 - acc:
0.8125
Epoch 00025: saving model to /content/data/model/weights.epoch_25.hdf5
163/163 [==============================] - 86s 526ms/step - loss: 0.1023 -
acc: 0.9630 - val_loss: 0.2242 - val_acc: 0.8125
Epoch 26/100
162/163 [============================>.] - ETA: 0s - loss: 0.1024 - acc: 0
.9603Epoch 1/100
  1/163 [..............................] - ETA: 55s - loss: 0.2564 - acc:
0.8750
Epoch 00026: saving model to /content/data/model/weights.epoch_26.hdf5
163/163 [==============================] - 86s 526ms/step - loss: 0.1021 -
acc: 0.9605 - val_loss: 0.2564 - val_acc: 0.8750
Epoch 27/100
162/163 [============================>.] - ETA: 0s - loss: 0.1021 - acc: 0
.9620Epoch 1/100
  1/163 [..............................] - ETA: 56s - loss: 0.2047 - acc:
0.8125
Epoch 00027: saving model to /content/data/model/weights.epoch_27.hdf5
163/163 [==============================] - 87s 535ms/step - loss: 0.1017 -
acc: 0.9622 - val_loss: 0.2047 - val_acc: 0.8125
Epoch 28/100
162/163 [============================>.] - ETA: 0s - loss: 0.1003 - acc: 0
.9633Epoch 1/100
  1/163 [..............................] - ETA: 1:01 - loss: 0.2010 - acc:
0.8125
Epoch 00028: saving model to /content/data/model/weights.epoch_28.hdf5
163/163 [==============================] - 88s 540ms/step - loss: 0.1001 -
acc: 0.9636 - val_loss: 0.2010 - val_acc: 0.8125
Epoch 29/100
162/163 [============================>.] - ETA: 0s - loss: 0.1011 - acc: 0
.9633Epoch 1/100
  1/163 [..............................] - ETA: 56s - loss: 0.2315 - acc:
0.8750
Epoch 00029: saving model to /content/data/model/weights.epoch_29.hdf5
163/163 [==============================] - 87s 536ms/step - loss: 0.1009 -
acc: 0.9636 - val_loss: 0.2315 - val_acc: 0.8750
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Epoch 30/100
162/163 [============================>.] - ETA: 0s - loss: 0.1033 - acc: 0
.9616Epoch 1/100
  1/163 [..............................] - ETA: 54s - loss: 0.1830 - acc:
0.8750
Epoch 00030: saving model to /content/data/model/weights.epoch_30.hdf5
163/163 [==============================] - 89s 544ms/step - loss: 0.1030 -
acc: 0.9617 - val_loss: 0.1830 - val_acc: 0.8750
Epoch 31/100
162/163 [============================>.] - ETA: 0s - loss: 0.1006 - acc: 0
.9639Epoch 1/100
  1/163 [..............................] - ETA: 57s - loss: 0.2018 - acc:
0.8125
Epoch 00031: saving model to /content/data/model/weights.epoch_31.hdf5
163/163 [==============================] - 87s 536ms/step - loss: 0.1002 -
acc: 0.9641 - val_loss: 0.2018 - val_acc: 0.8125
Epoch 32/100
162/163 [============================>.] - ETA: 0s - loss: 0.0976 - acc: 0
.9637Epoch 1/100
  1/163 [..............................] - ETA: 57s - loss: 0.2475 - acc:
0.8750
Epoch 00032: saving model to /content/data/model/weights.epoch_32.hdf5
163/163 [==============================] - 88s 539ms/step - loss: 0.0984 -
acc: 0.9632 - val_loss: 0.2475 - val_acc: 0.8750
Epoch 33/100
162/163 [============================>.] - ETA: 0s - loss: 0.0973 - acc: 0
.9645Epoch 1/100
  1/163 [..............................] - ETA: 57s - loss: 0.2048 - acc:
0.8125
Epoch 00033: saving model to /content/data/model/weights.epoch_33.hdf5
163/163 [==============================] - 87s 535ms/step - loss: 0.0970 -
acc: 0.9647 - val_loss: 0.2048 - val_acc: 0.8125
Epoch 34/100
162/163 [============================>.] - ETA: 0s - loss: 0.0944 - acc: 0
.9651Epoch 1/100
  1/163 [..............................] - ETA: 1:00 - loss: 0.2112 - acc:
0.8125
Epoch 00034: saving model to /content/data/model/weights.epoch_34.hdf5
163/163 [==============================] - 87s 536ms/step - loss: 0.0945 -
acc: 0.9649 - val_loss: 0.2112 - val_acc: 0.8125
Epoch 35/100
162/163 [============================>.] - ETA: 0s - loss: 0.0955 - acc: 0
.9651Epoch 1/100
  1/163 [..............................] - ETA: 56s - loss: 0.1910 - acc:
0.8750
Epoch 00035: saving model to /content/data/model/weights.epoch_35.hdf5
163/163 [==============================] - 87s 534ms/step - loss: 0.0950 -
acc: 0.9653 - val_loss: 0.1910 - val_acc: 0.8750
Epoch 36/100
162/163 [============================>.] - ETA: 0s - loss: 0.0929 - acc: 0
.9630Epoch 1/100
  1/163 [..............................] - ETA: 55s - loss: 0.2024 - acc:
0.8125
Epoch 00036: saving model to /content/data/model/weights.epoch_36.hdf5
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163/163 [==============================] - 87s 531ms/step - loss: 0.0928 -
acc: 0.9630 - val_loss: 0.2024 - val_acc: 0.8125
Epoch 37/100
162/163 [============================>.] - ETA: 0s - loss: 0.0924 - acc: 0
.9637Epoch 1/100
  1/163 [..............................] - ETA: 58s - loss: 0.1762 - acc:
0.9375
Epoch 00037: saving model to /content/data/model/weights.epoch_37.hdf5
163/163 [==============================] - 87s 534ms/step - loss: 0.0921 -
acc: 0.9640 - val_loss: 0.1762 - val_acc: 0.9375
Epoch 38/100
162/163 [============================>.] - ETA: 0s - loss: 0.0965 - acc: 0
.9616Epoch 1/100
  1/163 [..............................] - ETA: 58s - loss: 0.1911 - acc:
0.8750
Epoch 00038: saving model to /content/data/model/weights.epoch_38.hdf5
163/163 [==============================] - 87s 535ms/step - loss: 0.0967 -
acc: 0.9615 - val_loss: 0.1911 - val_acc: 0.8750
Epoch 39/100
162/163 [============================>.] - ETA: 0s - loss: 0.0928 - acc: 0
.9651Epoch 1/100
  1/163 [..............................] - ETA: 55s - loss: 0.2018 - acc:
0.8125
Epoch 00039: saving model to /content/data/model/weights.epoch_39.hdf5
163/163 [==============================] - 88s 538ms/step - loss: 0.0925 -
acc: 0.9653 - val_loss: 0.2018 - val_acc: 0.8125
Epoch 40/100
162/163 [============================>.] - ETA: 0s - loss: 0.0912 - acc: 0
.9668Epoch 1/100
  1/163 [..............................] - ETA: 56s - loss: 0.1802 - acc:
0.8750
Epoch 00040: saving model to /content/data/model/weights.epoch_40.hdf5
163/163 [==============================] - 87s 537ms/step - loss: 0.0910 -
acc: 0.9670 - val_loss: 0.1802 - val_acc: 0.8750
Epoch 41/100
162/163 [============================>.] - ETA: 0s - loss: 0.0908 - acc: 0
.9676Epoch 1/100
  1/163 [..............................] - ETA: 55s - loss: 0.1927 - acc:
0.8750
Epoch 00041: saving model to /content/data/model/weights.epoch_41.hdf5
163/163 [==============================] - 88s 539ms/step - loss: 0.0908 -
acc: 0.9676 - val_loss: 0.1927 - val_acc: 0.8750
Epoch 42/100
162/163 [============================>.] - ETA: 0s - loss: 0.0909 - acc: 0
.9660Epoch 1/100
  1/163 [..............................] - ETA: 54s - loss: 0.2105 - acc:
0.8750
Epoch 00042: saving model to /content/data/model/weights.epoch_42.hdf5
163/163 [==============================] - 87s 534ms/step - loss: 0.0911 -
acc: 0.9657 - val_loss: 0.2105 - val_acc: 0.8750
Epoch 43/100
162/163 [============================>.] - ETA: 0s - loss: 0.0938 - acc: 0
.9660Epoch 1/100
  1/163 [..............................] - ETA: 57s - loss: 0.1974 - acc:
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0.8125
Epoch 00043: saving model to /content/data/model/weights.epoch_43.hdf5
163/163 [==============================] - 88s 538ms/step - loss: 0.0934 -
acc: 0.9663 - val_loss: 0.1974 - val_acc: 0.8125
Epoch 44/100
162/163 [============================>.] - ETA: 0s - loss: 0.0898 - acc: 0
.9655Epoch 1/100
  1/163 [..............................] - ETA: 57s - loss: 0.2004 - acc:
0.8125
Epoch 00044: saving model to /content/data/model/weights.epoch_44.hdf5
163/163 [==============================] - 87s 534ms/step - loss: 0.0900 -
acc: 0.9651 - val_loss: 0.2004 - val_acc: 0.8125
Epoch 45/100
162/163 [============================>.] - ETA: 0s - loss: 0.0910 - acc: 0
.9651Epoch 1/100
  1/163 [..............................] - ETA: 55s - loss: 0.2159 - acc:
0.8750
Epoch 00045: saving model to /content/data/model/weights.epoch_45.hdf5
163/163 [==============================] - 87s 533ms/step - loss: 0.0911 -
acc: 0.9649 - val_loss: 0.2159 - val_acc: 0.8750
Epoch 46/100
162/163 [============================>.] - ETA: 0s - loss: 0.0867 - acc: 0
.9697Epoch 1/100
  1/163 [..............................] - ETA: 55s - loss: 0.2005 - acc:
0.8750
Epoch 00046: saving model to /content/data/model/weights.epoch_46.hdf5
163/163 [==============================] - 87s 534ms/step - loss: 0.0866 -
acc: 0.9697 - val_loss: 0.2005 - val_acc: 0.8750
Epoch 47/100
162/163 [============================>.] - ETA: 0s - loss: 0.0913 - acc: 0
.9649Epoch 1/100
  1/163 [..............................] - ETA: 56s - loss: 0.1812 - acc:
0.8750
Epoch 00047: saving model to /content/data/model/weights.epoch_47.hdf5
163/163 [==============================] - 87s 535ms/step - loss: 0.0916 -
acc: 0.9647 - val_loss: 0.1812 - val_acc: 0.8750
Epoch 48/100
162/163 [============================>.] - ETA: 0s - loss: 0.0862 - acc: 0
.9682Epoch 1/100
  1/163 [..............................] - ETA: 58s - loss: 0.1603 - acc:
0.9375
Epoch 00048: saving model to /content/data/model/weights.epoch_48.hdf5
163/163 [==============================] - 87s 534ms/step - loss: 0.0864 -
acc: 0.9682 - val_loss: 0.1603 - val_acc: 0.9375
Epoch 49/100
162/163 [============================>.] - ETA: 0s - loss: 0.0888 - acc: 0
.9664Epoch 1/100
  1/163 [..............................] - ETA: 1:00 - loss: 0.1889 - acc:
0.8750
Epoch 00049: saving model to /content/data/model/weights.epoch_49.hdf5
163/163 [==============================] - 87s 535ms/step - loss: 0.0890 -
acc: 0.9661 - val_loss: 0.1889 - val_acc: 0.8750
Epoch 50/100
162/163 [============================>.] - ETA: 0s - loss: 0.0864 - acc: 0
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.9662Epoch 1/100
  1/163 [..............................] - ETA: 55s - loss: 0.1819 - acc: 
0.9375
Epoch 00050: saving model to /content/data/model/weights.epoch_50.hdf5
163/163 [==============================] - 87s 533ms/step - loss: 0.0864 - 
acc: 0.9663 - val_loss: 0.1819 - val_acc: 0.9375
Epoch 51/100
162/163 [============================>.] - ETA: 0s - loss: 0.0884 - acc: 0
.9670Epoch 1/100
  1/163 [..............................] - ETA: 58s - loss: 0.2143 - acc: 
0.8750
Epoch 00051: saving model to /content/data/model/weights.epoch_51.hdf5
163/163 [==============================] - 87s 532ms/step - loss: 0.0884 - 
acc: 0.9670 - val_loss: 0.2143 - val_acc: 0.8750
Epoch 52/100
162/163 [============================>.] - ETA: 0s - loss: 0.0865 - acc: 0
.9672Epoch 1/100
  1/163 [..............................] - ETA: 56s - loss: 0.1663 - acc: 
0.9375
Epoch 00052: saving model to /content/data/model/weights.epoch_52.hdf5
163/163 [==============================] - 87s 534ms/step - loss: 0.0862 - 
acc: 0.9674 - val_loss: 0.1663 - val_acc: 0.9375
Epoch 53/100
162/163 [============================>.] - ETA: 0s - loss: 0.0898 - acc: 0
.9666Epoch 1/100
  1/163 [..............................] - ETA: 57s - loss: 0.1647 - acc: 
0.9375
Epoch 00053: saving model to /content/data/model/weights.epoch_53.hdf5
163/163 [==============================] - 87s 535ms/step - loss: 0.0896 - 
acc: 0.9668 - val_loss: 0.1647 - val_acc: 0.9375
Epoch 54/100
162/163 [============================>.] - ETA: 0s - loss: 0.0866 - acc: 0
.9699Epoch 1/100
  1/163 [..............................] - ETA: 56s - loss: 0.1743 - acc: 
0.9375
Epoch 00054: saving model to /content/data/model/weights.epoch_54.hdf5
163/163 [==============================] - 87s 533ms/step - loss: 0.0870 - 
acc: 0.9697 - val_loss: 0.1743 - val_acc: 0.9375
Epoch 55/100
162/163 [============================>.] - ETA: 0s - loss: 0.0831 - acc: 0
.9691Epoch 1/100
  1/163 [..............................] - ETA: 57s - loss: 0.1566 - acc: 
0.9375
Epoch 00055: saving model to /content/data/model/weights.epoch_55.hdf5
163/163 [==============================] - 86s 526ms/step - loss: 0.0828 - 
acc: 0.9693 - val_loss: 0.1566 - val_acc: 0.9375
Epoch 56/100
162/163 [============================>.] - ETA: 0s - loss: 0.0857 - acc: 0
.9701Epoch 1/100
  1/163 [..............................] - ETA: 56s - loss: 0.1982 - acc: 
0.8750
Epoch 00056: saving model to /content/data/model/weights.epoch_56.hdf5
163/163 [==============================] - 86s 530ms/step - loss: 0.0853 - 
acc: 0.9703 - val_loss: 0.1982 - val_acc: 0.8750
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```
Epoch 57/100
162/163 [============================>.] - ETA: 0s - loss: 0.0852 - acc: 0
.9701Epoch 1/100
  1/163 [..............................] - ETA: 59s - loss: 0.1568 - acc:
0.9375
Epoch 00057: saving model to /content/data/model/weights.epoch_57.hdf5
163/163 [==============================] - 87s 534ms/step - loss: 0.0853 -
acc: 0.9699 - val_loss: 0.1568 - val_acc: 0.9375
Epoch 58/100
162/163 [============================>.] - ETA: 0s - loss: 0.0845 - acc: 0
.9680Epoch 1/100
  1/163 [..............................] - ETA: 54s - loss: 0.1788 - acc:
0.8750
Epoch 00058: saving model to /content/data/model/weights.epoch_58.hdf5
163/163 [==============================] - 87s 535ms/step - loss: 0.0843 -
acc: 0.9680 - val_loss: 0.1788 - val_acc: 0.8750
Epoch 59/100
162/163 [============================>.] - ETA: 0s - loss: 0.0808 - acc: 0
.9678Epoch 1/100
  1/163 [..............................] - ETA: 54s - loss: 0.1648 - acc:
0.8750
Epoch 00059: saving model to /content/data/model/weights.epoch_59.hdf5
163/163 [==============================] - 87s 531ms/step - loss: 0.0816 -
acc: 0.9676 - val_loss: 0.1648 - val_acc: 0.8750
Epoch 60/100
162/163 [============================>.] - ETA: 0s - loss: 0.0897 - acc: 0
.9653Epoch 1/100
  1/163 [..............................] - ETA: 54s - loss: 0.1757 - acc:
0.8750
Epoch 00060: saving model to /content/data/model/weights.epoch_60.hdf5
163/163 [==============================] - 87s 531ms/step - loss: 0.0898 -
acc: 0.9653 - val_loss: 0.1757 - val_acc: 0.8750
Epoch 61/100
162/163 [============================>.] - ETA: 0s - loss: 0.0845 - acc: 0
.9701Epoch 1/100
  1/163 [..............................] - ETA: 59s - loss: 0.1680 - acc:
0.8750
Epoch 00061: saving model to /content/data/model/weights.epoch_61.hdf5
163/163 [==============================] - 88s 537ms/step - loss: 0.0843 -
acc: 0.9703 - val_loss: 0.1680 - val_acc: 0.8750
Epoch 62/100
162/163 [============================>.] - ETA: 0s - loss: 0.0810 - acc: 0
.9730Epoch 1/100
  1/163 [..............................] - ETA: 55s - loss: 0.1468 - acc:
0.9375
Epoch 00062: saving model to /content/data/model/weights.epoch_62.hdf5
163/163 [==============================] - 87s 534ms/step - loss: 0.0809 -
acc: 0.9732 - val_loss: 0.1468 - val_acc: 0.9375
Epoch 63/100
162/163 [============================>.] - ETA: 0s - loss: 0.0815 - acc: 0
.9693Epoch 1/100
  1/163 [..............................] - ETA: 55s - loss: 0.1579 - acc:
0.8750
Epoch 00063: saving model to /content/data/model/weights.epoch_63.hdf5
```

```
163/163 [==============================] - 87s 534ms/step - loss: 0.0815 -
acc: 0.9691 - val_loss: 0.1579 - val_acc: 0.8750
Epoch 64/100
162/163 [============================>.] - ETA: 0s - loss: 0.0817 - acc: 0
.9697Epoch 1/100
  1/163 [..............................] - ETA: 58s - loss: 0.1476 - acc:
0.9375
Epoch 00064: saving model to /content/data/model/weights.epoch_64.hdf5
163/163 [==============================] - 88s 539ms/step - loss: 0.0816 -
acc: 0.9697 - val_loss: 0.1476 - val_acc: 0.9375
Epoch 65/100
162/163 [============================>.] - ETA: 0s - loss: 0.0849 - acc: 0
.9695Epoch 1/100
  1/163 [..............................] - ETA: 58s - loss: 0.1696 - acc:
0.9375
Epoch 00065: saving model to /content/data/model/weights.epoch_65.hdf5
163/163 [==============================] - 87s 533ms/step - loss: 0.0849 -
acc: 0.9695 - val_loss: 0.1696 - val_acc: 0.9375
Epoch 66/100
162/163 [============================>.] - ETA: 0s - loss: 0.0816 - acc: 0
.9707Epoch 1/100
  1/163 [..............................] - ETA: 58s - loss: 0.1945 - acc:
0.8750
Epoch 00066: saving model to /content/data/model/weights.epoch_66.hdf5
163/163 [==============================] - 88s 538ms/step - loss: 0.0815 -
acc: 0.9709 - val_loss: 0.1945 - val_acc: 0.8750
Epoch 67/100
162/163 [============================>.] - ETA: 0s - loss: 0.0804 - acc: 0
.9697Epoch 1/100
  1/163 [..............................] - ETA: 58s - loss: 0.1503 - acc:
0.8750
Epoch 00067: saving model to /content/data/model/weights.epoch_67.hdf5
163/163 [==============================] - 88s 541ms/step - loss: 0.0802 -
acc: 0.9699 - val_loss: 0.1503 - val_acc: 0.8750
Epoch 68/100
162/163 [============================>.] - ETA: 0s - loss: 0.0798 - acc: 0
.9711Epoch 1/100
  1/163 [..............................] - ETA: 56s - loss: 0.1394 - acc:
0.9375
Epoch 00068: saving model to /content/data/model/weights.epoch_68.hdf5
163/163 [==============================] - 87s 535ms/step - loss: 0.0794 -
acc: 0.9712 - val_loss: 0.1394 - val_acc: 0.9375
Epoch 69/100
162/163 [============================>.] - ETA: 0s - loss: 0.0813 - acc: 0
.9697Epoch 1/100
  1/163 [..............................] - ETA: 54s - loss: 0.1573 - acc:
0.9375
Epoch 00069: saving model to /content/data/model/weights.epoch_69.hdf5
163/163 [==============================] - 88s 538ms/step - loss: 0.0814 -
acc: 0.9695 - val_loss: 0.1573 - val_acc: 0.9375
Epoch 70/100
162/163 [============================>.] - ETA: 0s - loss: 0.0798 - acc: 0
.9688Epoch 1/100
  1/163 [..............................] - ETA: 58s - loss: 0.1837 - acc:
```

```
0.8750
Epoch 00070: saving model to /content/data/model/weights.epoch_70.hdf5
163/163 [==============================] - 88s 539ms/step - loss: 0.0798 -
acc: 0.9688 - val_loss: 0.1837 - val_acc: 0.8750
Epoch 71/100
162/163 [============================>.] - ETA: 0s - loss: 0.0824 - acc: 0
.9701Epoch 1/100
  1/163 [..............................] - ETA: 57s - loss: 0.1669 - acc:
0.8750
Epoch 00071: saving model to /content/data/model/weights.epoch_71.hdf5
163/163 [==============================] - 87s 533ms/step - loss: 0.0822 -
acc: 0.9703 - val_loss: 0.1669 - val_acc: 0.8750
Epoch 72/100
162/163 [============================>.] - ETA: 0s - loss: 0.0766 - acc: 0
.9715Epoch 1/100
  1/163 [..............................] - ETA: 55s - loss: 0.1370 - acc:
0.9375
Epoch 00072: saving model to /content/data/model/weights.epoch_72.hdf5
163/163 [==============================] - 87s 536ms/step - loss: 0.0766 -
acc: 0.9714 - val_loss: 0.1370 - val_acc: 0.9375
Epoch 73/100
162/163 [============================>.] - ETA: 0s - loss: 0.0808 - acc: 0
.9689Epoch 1/100
  1/163 [..............................] - ETA: 56s - loss: 0.1599 - acc:
0.9375
Epoch 00073: saving model to /content/data/model/weights.epoch_73.hdf5
163/163 [==============================] - 88s 540ms/step - loss: 0.0820 -
acc: 0.9686 - val_loss: 0.1599 - val_acc: 0.9375
Epoch 74/100
162/163 [============================>.] - ETA: 0s - loss: 0.0779 - acc: 0
.9722Epoch 1/100
  1/163 [..............................] - ETA: 54s - loss: 0.1502 - acc:
0.9375
Epoch 00074: saving model to /content/data/model/weights.epoch_74.hdf5
163/163 [==============================] - 88s 541ms/step - loss: 0.0776 -
acc: 0.9724 - val_loss: 0.1502 - val_acc: 0.9375
Epoch 75/100
162/163 [============================>.] - ETA: 0s - loss: 0.0799 - acc: 0
.9711Epoch 1/100
  1/163 [..............................] - ETA: 58s - loss: 0.1747 - acc:
0.9375
Epoch 00075: saving model to /content/data/model/weights.epoch_75.hdf5
163/163 [==============================] - 88s 538ms/step - loss: 0.0803 -
acc: 0.9709 - val_loss: 0.1747 - val_acc: 0.9375
Epoch 76/100
162/163 [============================>.] - ETA: 0s - loss: 0.0821 - acc: 0
.9691Epoch 1/100
  1/163 [..............................] - ETA: 58s - loss: 0.1513 - acc:
0.9375
Epoch 00076: saving model to /content/data/model/weights.epoch_76.hdf5
163/163 [==============================] - 88s 541ms/step - loss: 0.0822 -
acc: 0.9691 - val_loss: 0.1513 - val_acc: 0.9375
Epoch 77/100
162/163 [============================>.] - ETA: 0s - loss: 0.0761 - acc: 0
```

```
.9722Epoch 1/100
  1/163 [..............................] - ETA: 53s - loss: 0.1408 - acc:
0.9375
Epoch 00077: saving model to /content/data/model/weights.epoch_77.hdf5
163/163 [==============================] - 88s 537ms/step - loss: 0.0757 -
acc: 0.9724 - val_loss: 0.1408 - val_acc: 0.9375
Epoch 78/100
162/163 [============================>.] - ETA: 0s - loss: 0.0768 - acc: 0
.9726Epoch 1/100
  1/163 [..............................] - ETA: 59s - loss: 0.1555 - acc:
0.9375
Epoch 00078: saving model to /content/data/model/weights.epoch_78.hdf5
163/163 [==============================] - 88s 540ms/step - loss: 0.0771 -
acc: 0.9722 - val_loss: 0.1555 - val_acc: 0.9375
Epoch 79/100
162/163 [============================>.] - ETA: 0s - loss: 0.0781 - acc: 0
.9693Epoch 1/100
  1/163 [..............................] - ETA: 54s - loss: 0.1834 - acc:
0.8750
Epoch 00079: saving model to /content/data/model/weights.epoch_79.hdf5
163/163 [==============================] - 88s 540ms/step - loss: 0.0783 -
acc: 0.9693 - val_loss: 0.1834 - val_acc: 0.8750
Epoch 80/100
162/163 [============================>.] - ETA: 0s - loss: 0.0764 - acc: 0
.9713Epoch 1/100
  1/163 [..............................] - ETA: 56s - loss: 0.1461 - acc:
0.9375
Epoch 00080: saving model to /content/data/model/weights.epoch_80.hdf5
163/163 [==============================] - 88s 540ms/step - loss: 0.0762 -
acc: 0.9714 - val_loss: 0.1461 - val_acc: 0.9375
Epoch 81/100
162/163 [============================>.] - ETA: 0s - loss: 0.0774 - acc: 0
.9715Epoch 1/100
  1/163 [..............................] - ETA: 54s - loss: 0.1406 - acc:
0.9375
Epoch 00081: saving model to /content/data/model/weights.epoch_81.hdf5
163/163 [==============================] - 88s 537ms/step - loss: 0.0771 -
acc: 0.9716 - val_loss: 0.1406 - val_acc: 0.9375
Epoch 82/100
162/163 [============================>.] - ETA: 0s - loss: 0.0800 - acc: 0
.9697Epoch 1/100
  1/163 [..............................] - ETA: 56s - loss: 0.1521 - acc:
1.0000
Epoch 00082: saving model to /content/data/model/weights.epoch_82.hdf5
163/163 [==============================] - 87s 537ms/step - loss: 0.0798 -
acc: 0.9699 - val_loss: 0.1521 - val_acc: 1.0000
Epoch 83/100
162/163 [============================>.] - ETA: 0s - loss: 0.0781 - acc: 0
.9707Epoch 1/100
  1/163 [..............................] - ETA: 59s - loss: 0.1458 - acc:
0.9375
Epoch 00083: saving model to /content/data/model/weights.epoch_83.hdf5
163/163 [==============================] - 88s 537ms/step - loss: 0.0784 -
acc: 0.9707 - val_loss: 0.1458 - val_acc: 0.9375
```

```
Epoch 84/100
162/163 [============================>.] - ETA: 0s - loss: 0.0777 - acc: 0
.9730Epoch 1/100
  1/163 [..............................] - ETA: 58s - loss: 0.1548 - acc:
1.0000
Epoch 00084: saving model to /content/data/model/weights.epoch_84.hdf5
163/163 [==============================] - 88s 537ms/step - loss: 0.0774 -
acc: 0.9732 - val_loss: 0.1548 - val_acc: 1.0000
Epoch 85/100
162/163 [============================>.] - ETA: 0s - loss: 0.0763 - acc: 0
.9713Epoch 1/100
  1/163 [..............................] - ETA: 59s - loss: 0.1450 - acc:
0.9375
Epoch 00085: saving model to /content/data/model/weights.epoch_85.hdf5
163/163 [==============================] - 87s 534ms/step - loss: 0.0763 -
acc: 0.9712 - val_loss: 0.1450 - val_acc: 0.9375
Epoch 86/100
162/163 [============================>.] - ETA: 0s - loss: 0.0761 - acc: 0
.9713Epoch 1/100
  1/163 [..............................] - ETA: 58s - loss: 0.1456 - acc:
0.9375
Epoch 00086: saving model to /content/data/model/weights.epoch_86.hdf5
163/163 [==============================] - 88s 538ms/step - loss: 0.0762 -
acc: 0.9711 - val_loss: 0.1456 - val_acc: 0.9375
Epoch 87/100
162/163 [============================>.] - ETA: 0s - loss: 0.0731 - acc: 0
.9751Epoch 1/100
  1/163 [..............................] - ETA: 58s - loss: 0.1490 - acc:
0.9375
Epoch 00087: saving model to /content/data/model/weights.epoch_87.hdf5
163/163 [==============================] - 88s 540ms/step - loss: 0.0728 -
acc: 0.9753 - val_loss: 0.1490 - val_acc: 0.9375
Epoch 88/100
162/163 [============================>.] - ETA: 0s - loss: 0.0781 - acc: 0
.9711Epoch 1/100
  1/163 [..............................] - ETA: 57s - loss: 0.1489 - acc:
0.9375
Epoch 00088: saving model to /content/data/model/weights.epoch_88.hdf5
163/163 [==============================] - 87s 536ms/step - loss: 0.0779 -
acc: 0.9712 - val_loss: 0.1489 - val_acc: 0.9375
Epoch 89/100
162/163 [============================>.] - ETA: 0s - loss: 0.0759 - acc: 0
.9728Epoch 1/100
  1/163 [..............................] - ETA: 56s - loss: 0.1720 - acc:
0.9375
Epoch 00089: saving model to /content/data/model/weights.epoch_89.hdf5
163/163 [==============================] - 88s 538ms/step - loss: 0.0766 -
acc: 0.9724 - val_loss: 0.1720 - val_acc: 0.9375
Epoch 90/100
162/163 [============================>.] - ETA: 0s - loss: 0.0771 - acc: 0
.9707Epoch 1/100
  1/163 [..............................] - ETA: 55s - loss: 0.1625 - acc:
1.0000
Epoch 00090: saving model to /content/data/model/weights.epoch_90.hdf5
```

```
163/163 [==============================] - 88s 539ms/step - loss: 0.0770 -
acc: 0.9707 - val_loss: 0.1625 - val_acc: 1.0000
Epoch 91/100
162/163 [============================>.] - ETA: 0s - loss: 0.0803 - acc: 0
.9713Epoch 1/100
  1/163 [..............................] - ETA: 55s - loss: 0.1384 - acc:
0.9375
Epoch 00091: saving model to /content/data/model/weights.epoch_91.hdf5
163/163 [==============================] - 88s 540ms/step - loss: 0.0799 -
acc: 0.9714 - val_loss: 0.1384 - val_acc: 0.9375
Epoch 92/100
162/163 [============================>.] - ETA: 0s - loss: 0.0790 - acc: 0
.9745Epoch 1/100
  1/163 [..............................] - ETA: 55s - loss: 0.1363 - acc:
0.9375
Epoch 00092: saving model to /content/data/model/weights.epoch_92.hdf5
163/163 [==============================] - 88s 537ms/step - loss: 0.0788 -
acc: 0.9747 - val_loss: 0.1363 - val_acc: 0.9375
Epoch 93/100
162/163 [============================>.] - ETA: 0s - loss: 0.0752 - acc: 0
.9742Epoch 1/100
  1/163 [..............................] - ETA: 59s - loss: 0.1424 - acc:
1.0000
Epoch 00093: saving model to /content/data/model/weights.epoch_93.hdf5
163/163 [==============================] - 88s 538ms/step - loss: 0.0753 -
acc: 0.9739 - val_loss: 0.1424 - val_acc: 1.0000
Epoch 94/100
162/163 [============================>.] - ETA: 0s - loss: 0.0742 - acc: 0
.9720Epoch 1/100
  1/163 [..............................] - ETA: 57s - loss: 0.1613 - acc:
0.9375
Epoch 00094: saving model to /content/data/model/weights.epoch_94.hdf5
163/163 [==============================] - 88s 538ms/step - loss: 0.0740 -
acc: 0.9722 - val_loss: 0.1613 - val_acc: 0.9375
Epoch 95/100
162/163 [============================>.] - ETA: 0s - loss: 0.0714 - acc: 0
.9745Epoch 1/100
  1/163 [..............................] - ETA: 59s - loss: 0.1331 - acc:
0.9375
Epoch 00095: saving model to /content/data/model/weights.epoch_95.hdf5
163/163 [==============================] - 88s 539ms/step - loss: 0.0714 -
acc: 0.9745 - val_loss: 0.1331 - val_acc: 0.9375
Epoch 96/100
162/163 [============================>.] - ETA: 0s - loss: 0.0741 - acc: 0
.9736Epoch 1/100
  1/163 [..............................] - ETA: 54s - loss: 0.1283 - acc:
0.9375
Epoch 00096: saving model to /content/data/model/weights.epoch_96.hdf5
163/163 [==============================] - 88s 540ms/step - loss: 0.0744 -
acc: 0.9735 - val_loss: 0.1283 - val_acc: 0.9375
Epoch 97/100
162/163 [============================>.] - ETA: 0s - loss: 0.0765 - acc: 0
.9701Epoch 1/100
  1/163 [..............................] - ETA: 54s - loss: 0.1328 - acc:
```

```
0.9375
Epoch 00097: saving model to /content/data/model/weights.epoch_97.hdf5
163/163 [==============================] - 87s 535ms/step - loss: 0.0761 -
acc: 0.9703 - val_loss: 0.1328 - val_acc: 0.9375
Epoch 98/100
162/163 [============================>.] - ETA: 0s - loss: 0.0748 - acc: 0
.9728Epoch 1/100
  1/163 [..............................] - ETA: 57s - loss: 0.1357 - acc:
0.9375
Epoch 00098: saving model to /content/data/model/weights.epoch_98.hdf5
163/163 [==============================] - 88s 540ms/step - loss: 0.0747 -
acc: 0.9728 - val_loss: 0.1357 - val_acc: 0.9375
Epoch 99/100
162/163 [============================>.] - ETA: 0s - loss: 0.0751 - acc: 0
.9724Epoch 1/100
  1/163 [..............................] - ETA: 54s - loss: 0.1775 - acc:
0.9375
Epoch 00099: saving model to /content/data/model/weights.epoch_99.hdf5
163/163 [==============================] - 87s 536ms/step - loss: 0.0750 -
acc: 0.9724 - val_loss: 0.1775 - val_acc: 0.9375
Epoch 100/100
162/163 [============================>.] - ETA: 0s - loss: 0.0761 - acc: 0
.9730Epoch 1/100
  1/163 [..............................] - ETA: 1:01 - loss: 0.1396 - acc:
0.9375
Epoch 00100: saving model to /content/data/model/weights.epoch_100.hdf5
163/163 [==============================] - 88s 538ms/step - loss: 0.0758 -
acc: 0.9732 - val_loss: 0.1396 - val_acc: 0.9375
```

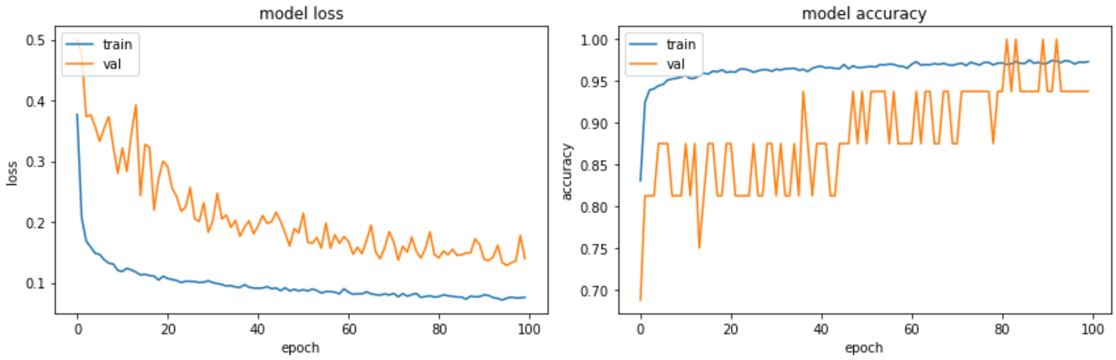
```
import matplotlib.pyplot as plt
def plot_learning_curves(history):
    plt.figure(figsize=(12,4))

    plt.subplot(1,2,1)
    plt.plot(history.history['loss'])
    plt.plot(history.history['val_loss'])
    plt.title('model loss')
    plt.ylabel('loss')
    plt.xlabel('epoch')
    plt.legend(['train', 'val'], loc='upper left')

    plt.subplot(1,2,2)
    plt.plot(history.history['acc'])
    plt.plot(history.history['val_acc'])
    plt.title('model accuracy')
    plt.ylabel('accuracy')
    plt.xlabel('epoch')
    plt.legend(['train', 'val'], loc='upper left')

    plt.tight_layout()

plot_learning_curves(history)
```



png

```
idx = np.argmin(history.history['val_loss'])
model.load_weights("/content/data/model/weights.epoch_{:02d}.hdf5".format(
idx + 1))

print("Loading the best model")
print("epoch: {}, val_loss: {}, val_acc: {}".format(idx + 1, history.histo
ry['val_loss'][idx], history.history['val_acc'][idx]))
```

```
Loading the best model
epoch: 96, val_loss: 0.12834185361862183, val_acc: 0.9375
```

```
test_loss, test_acc = model.evaluate_generator(generator=test_generator, v
erbose=1)
```

```
20/20 [==============================] - 7s 342ms/step - loss: 0.2125 - ac
c: 0.9215
```

```
from sklearn.metrics import accuracy_score, confusion_matrix

test_generator.reset()
test_preds = model.predict_generator(test_generator, verbose=1)
test_preds = np.argmax(test_preds,axis=1)

acc = accuracy_score(test_generator.classes, test_preds)*100
cm = confusion_matrix(test_generator.classes, test_preds)
tn, fp, fn, tp = cm.ravel()

print('CONFUSION MATRIX ------------------')
print(cm)
# plot_confusion_matrix(cm, target_names=['NORMAL', 'PNEUMONIA'], normaliz
e=False)


print('\nTEST METRICS ----------------------')
precision = tp/(tp+fp)*100
recall = tp/(tp+fn)*100
print('Accuracy: {}%'.format(acc))
print('Precision: {}%'.format(precision))
print('Recall: {}%'.format(recall))
print('F1-score: {}'.format(2*precision*recall/(precision+recall)))
```

```
print('\nTRAIN METRIC ----------------------')
print('Train acc: {}%'.format(np.round((history.history['acc'][-1])*100, 1
4)))
```

```
20/20 [==============================] - 7s 354ms/step
CONFUSION MATRIX ------------------
[[203  31]
 [ 18 372]]

TEST METRICS ----------------------
Accuracy: 92.1474358974359%
Precision: 92.3076923076923%
Recall: 95.38461538461539%
F1-score: 93.82093316519547

TRAIN METRIC ----------------------
Train acc: 97.31594920158386%
```

9.6 Appendix F: VGG16 Model 1 Version 1.1.1.0.1

```
from __future__ import absolute_import, division, print_function, unicode_
literals
import tensorflow as tf

# Extract dataset
import os
import tarfile

import keras_preprocessing
from keras_preprocessing.image import ImageDataGenerator # Data preprocess
ing and augmentation

import sklearn
import numpy as np
```

The default version of TensorFlow in Colab will soon switch to TensorFlow 2.x. We recommend you upgrade now or ensure your notebook will continue to use TensorFlow 1.x via the %tensorflow_version 1.x magic: more info.

```
print(tf.__version__)
```

```
1.15.0
```

```
# Make folder for chest xray data
!mkdir /content/data/

# Make directory to save weights
!mkdir /content/data/model

# Make directory to logs for Tensorboard
!mkdir /content/data/graph

# Download dataset
!wget --no-check-certificate \
    https://s3.eu-central-1.amazonaws.com/public.unit8.co/data/chest_xray.
tar.gz \
    -O /content/data/chest_xray.tar.gz

tar = tarfile.open("data/chest_xray.tar.gz")
tar.extractall(path='./data/')
os.remove('data/chest_xray.tar.gz')
```

```
--2019-10-28 09:08:41--  https://s3.eu-central-1.amazonaws.com/public.unit
8.co/data/chest_xray.tar.gz
Resolving s3.eu-central-1.amazonaws.com (s3.eu-central-1.amazonaws.com)...
52.219.74.111
Connecting to s3.eu-central-1.amazonaws.com (s3.eu-central-1.amazonaws.com
)|52.219.74.111|:443... connected.
HTTP request sent, awaiting response... 200 OK
Length: 1225393795 (1.1G) [application/x-gzip]
Saving to: ‘/content/data/chest_xray.tar.gz’
```

```
/content/data/chest 100%[===================>]   1.14G  29.2MB/s    in 40s

2019-10-28 09:09:22 (28.9 MB/s) - ‘/content/data/chest_xray.tar.gz’ saved
[1225393795/1225393795]
```

Change log: > training_datagen –> ImageDataGenerator

trainable layer –> All except base

20 layers VGG16 model - base, flat, dense

Optimizer = RMSprop(learning_rate = 0.0001)

loss = categorical_crosscentropy

callback = [checkpoints]

epochs = 100

no class weight balancing

```
TRAINING_DIR = "/content/data/chest_xray/train"
VALIDATION_DIR = "/content/data/chest_xray/val"
TEST_DIR = "/content/data/chest_xray/test"

training_datagen = ImageDataGenerator(
    preprocessing_function=tf.keras.applications.vgg16.preprocess_input,
    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,
    # vertical_flip=True
    fill_mode='nearest'
)

validation_datagen = ImageDataGenerator(
    rescale = 1./255
)

test_datagen = ImageDataGenerator(
    rescale = 1./255
)

# Create training data batch
# TODO: Try grayscaling the image to see what will happen
train_generator = training_datagen.flow_from_directory(
    TRAINING_DIR,
    target_size=(150,150),
    class_mode='categorical'
)

validation_generator = validation_datagen.flow_from_directory(
    VALIDATION_DIR,
    target_size=(150,150),
```

```
    class_mode='categorical'
)

test_generator = test_datagen.flow_from_directory(
    TEST_DIR,
    target_size=(150,150),
    class_mode='categorical',
    shuffle=False
)

train_shape = train_generator.image_shape

tf.keras.backend.clear_session() # Destroys the current TF graph and creat
es a new one.

base_model = tf.keras.applications.VGG16(weights='imagenet', include_top=F
alse, input_shape=train_shape)

# Define the machine learning model
x = base_model.output
x = tf.keras.layers.Flatten()(x)
x = tf.keras.layers.Dense(2, 'softmax')(x)

model = tf.keras.Model(inputs=base_model.input, outputs=x)

# for layer in model.layers[0:20]:
#     layer.trainable = False

for layer in base_model.layers:
  layer.trainable = False

optimizer = tf.keras.optimizers.RMSprop(learning_rate=0.0001) # Lower lear
ning rate by x10

model.compile(loss='categorical_crossentropy',
              optimizer=optimizer,
              metrics=['accuracy'])

# Callbacks stuff
# Function to save the weights of the model after each epoch
checkpoint = tf.keras.callbacks.ModelCheckpoint(
    '/content/data/model/weights.epoch_{epoch:02d}.hdf5',
    monitor='val_accuracy',
    save_best_only=False,
    save_weights_only=False,
    mode='auto',
    verbose=1
)

# Function to stop training early if there's no improvement
early_stopping_monitor = tf.keras.callbacks.EarlyStopping(patience = 3, mo
nitor = "val_loss", mode="auto", verbose = 1)

lr_reduce = tf.keras.callbacks.ReduceLROnPlateau(monitor='val_loss', facto
```

```
r=0.3, patience=2, verbose=1, mode='max')

classweight = sklearn.utils.class_weight.compute_class_weight('balanced',
np.unique(train_generator.labels), train_generator.labels)
print(classweight)

# batch_size = 32
batch_size = 128
epochs = 100

step_size_train = train_generator.n // train_generator.batch_size
step_size_valid = validation_generator.n // validation_generator.batch_siz
e

# Training process
history = model.fit_generator(
    generator=train_generator,
    steps_per_epoch=step_size_train,
    epochs=epochs,
    # callbacks=[early_stopping_monitor],
    callbacks=[checkpoint],
    # shuffle=True,
    validation_data=validation_generator,
    # validation_steps= step_size_valid, #no because it's gonna be 0... if
leave alone its len(generator) which is equal to 1.
    # class_weight=classweight,
    verbose = 1
)

# test_loss, test_acc = model.evaluate_generator(generator=test_generator,
verbose=1)
```

```
Found 5216 images belonging to 2 classes.
Found 16 images belonging to 2 classes.
Found 624 images belonging to 2 classes.
[1.9448173  0.67303226]
Epoch 1/100
162/163 [============================>.] - ETA: 0s - loss: 0.3356 - acc: 0
.8574Epoch 1/100
  1/163 [..............................] - ETA: 4:27 - loss: 0.4553 - acc:
0.8125
Epoch 00001: saving model to /content/data/model/weights.epoch_01.hdf5
163/163 [==============================] - 90s 554ms/step - loss: 0.3354 -
acc: 0.8574 - val_loss: 0.4553 - val_acc: 0.8125
Epoch 2/100
162/163 [============================>.] - ETA: 0s - loss: 0.1994 - acc: 0
.9228Epoch 1/100
  1/163 [..............................] - ETA: 58s - loss: 0.3980 - acc:
0.8125
Epoch 00002: saving model to /content/data/model/weights.epoch_02.hdf5
163/163 [==============================] - 88s 541ms/step - loss: 0.1998 -
acc: 0.9225 - val_loss: 0.3980 - val_acc: 0.8125
Epoch 3/100
162/163 [============================>.] - ETA: 0s - loss: 0.1659 - acc: 0
```

```
.9354Epoch 1/100
  1/163 [..............................] - ETA: 55s - loss: 0.4058 - acc: 
0.8125
Epoch 00003: saving model to /content/data/model/weights.epoch_03.hdf5
163/163 [==============================] - 89s 549ms/step - loss: 0.1655 - 
acc: 0.9356 - val_loss: 0.4058 - val_acc: 0.8125
Epoch 4/100
162/163 [============================>.] - ETA: 0s - loss: 0.1547 - acc: 0
.9427Epoch 1/100
  1/163 [..............................] - ETA: 57s - loss: 0.3492 - acc: 
0.8125
Epoch 00004: saving model to /content/data/model/weights.epoch_04.hdf5
163/163 [==============================] - 89s 547ms/step - loss: 0.1555 - 
acc: 0.9423 - val_loss: 0.3492 - val_acc: 0.8125
Epoch 5/100
162/163 [============================>.] - ETA: 0s - loss: 0.1482 - acc: 0
.9475Epoch 1/100
  1/163 [..............................] - ETA: 56s - loss: 0.4583 - acc: 
0.7500
Epoch 00005: saving model to /content/data/model/weights.epoch_05.hdf5
163/163 [==============================] - 88s 541ms/step - loss: 0.1481 - 
acc: 0.9477 - val_loss: 0.4583 - val_acc: 0.7500
Epoch 6/100
162/163 [============================>.] - ETA: 0s - loss: 0.1397 - acc: 0
.9450Epoch 1/100
  1/163 [..............................] - ETA: 57s - loss: 0.4350 - acc: 
0.7500
Epoch 00006: saving model to /content/data/model/weights.epoch_06.hdf5
163/163 [==============================] - 88s 540ms/step - loss: 0.1394 - 
acc: 0.9454 - val_loss: 0.4350 - val_acc: 0.7500
Epoch 7/100
162/163 [============================>.] - ETA: 0s - loss: 0.1345 - acc: 0
.9525Epoch 1/100
  1/163 [..............................] - ETA: 54s - loss: 0.4254 - acc: 
0.7500
Epoch 00007: saving model to /content/data/model/weights.epoch_07.hdf5
163/163 [==============================] - 88s 539ms/step - loss: 0.1343 - 
acc: 0.9526 - val_loss: 0.4254 - val_acc: 0.7500
Epoch 8/100
162/163 [============================>.] - ETA: 0s - loss: 0.1274 - acc: 0
.9527Epoch 1/100
  1/163 [..............................] - ETA: 56s - loss: 0.4484 - acc: 
0.7500
Epoch 00008: saving model to /content/data/model/weights.epoch_08.hdf5
163/163 [==============================] - 88s 539ms/step - loss: 0.1267 - 
acc: 0.9530 - val_loss: 0.4484 - val_acc: 0.7500
Epoch 9/100
162/163 [============================>.] - ETA: 0s - loss: 0.1257 - acc: 0
.9545Epoch 1/100
  1/163 [..............................] - ETA: 56s - loss: 0.3802 - acc: 
0.8125
Epoch 00009: saving model to /content/data/model/weights.epoch_09.hdf5
163/163 [==============================] - 89s 544ms/step - loss: 0.1255 - 
acc: 0.9546 - val_loss: 0.3802 - val_acc: 0.8125
```

```
Epoch 10/100
162/163 [============================>.] - ETA: 0s - loss: 0.1275 - acc: 0
.9566Epoch 1/100
  1/163 [..............................] - ETA: 57s - loss: 0.3671 - acc:
0.8125
Epoch 00010: saving model to /content/data/model/weights.epoch_10.hdf5
163/163 [==============================] - 88s 543ms/step - loss: 0.1270 -
acc: 0.9567 - val_loss: 0.3671 - val_acc: 0.8125
Epoch 11/100
162/163 [============================>.] - ETA: 0s - loss: 0.1230 - acc: 0
.9549Epoch 1/100
  1/163 [..............................] - ETA: 57s - loss: 0.4039 - acc:
0.7500
Epoch 00011: saving model to /content/data/model/weights.epoch_11.hdf5
163/163 [==============================] - 88s 541ms/step - loss: 0.1236 -
acc: 0.9548 - val_loss: 0.4039 - val_acc: 0.7500
Epoch 12/100
162/163 [============================>.] - ETA: 0s - loss: 0.1188 - acc: 0
.9558Epoch 1/100
  1/163 [..............................] - ETA: 59s - loss: 0.3550 - acc:
0.8125
Epoch 00012: saving model to /content/data/model/weights.epoch_12.hdf5
163/163 [==============================] - 88s 541ms/step - loss: 0.1191 -
acc: 0.9555 - val_loss: 0.3550 - val_acc: 0.8125
Epoch 13/100
162/163 [============================>.] - ETA: 0s - loss: 0.1132 - acc: 0
.9597Epoch 1/100
  1/163 [..............................] - ETA: 56s - loss: 0.4012 - acc:
0.7500
Epoch 00013: saving model to /content/data/model/weights.epoch_13.hdf5
163/163 [==============================] - 89s 543ms/step - loss: 0.1128 -
acc: 0.9599 - val_loss: 0.4012 - val_acc: 0.7500
Epoch 14/100
162/163 [============================>.] - ETA: 0s - loss: 0.1194 - acc: 0
.9551Epoch 1/100
  1/163 [..............................] - ETA: 58s - loss: 0.3341 - acc:
0.8125
Epoch 00014: saving model to /content/data/model/weights.epoch_14.hdf5
163/163 [==============================] - 88s 539ms/step - loss: 0.1193 -
acc: 0.9551 - val_loss: 0.3341 - val_acc: 0.8125
Epoch 15/100
162/163 [============================>.] - ETA: 0s - loss: 0.1132 - acc: 0
.9601Epoch 1/100
  1/163 [..............................] - ETA: 57s - loss: 0.4175 - acc:
0.7500
Epoch 00015: saving model to /content/data/model/weights.epoch_15.hdf5
163/163 [==============================] - 89s 543ms/step - loss: 0.1131 -
acc: 0.9599 - val_loss: 0.4175 - val_acc: 0.7500
Epoch 16/100
162/163 [============================>.] - ETA: 0s - loss: 0.1148 - acc: 0
.9610Epoch 1/100
  1/163 [..............................] - ETA: 55s - loss: 0.3089 - acc:
0.8125
Epoch 00016: saving model to /content/data/model/weights.epoch_16.hdf5
```

```
163/163 [==============================] - 88s 541ms/step - loss: 0.1145 -
acc: 0.9611 - val_loss: 0.3089 - val_acc: 0.8125
Epoch 17/100
162/163 [============================>.] - ETA: 0s - loss: 0.1067 - acc: 0
.9593Epoch 1/100
  1/163 [..............................] - ETA: 57s - loss: 0.3082 - acc:
0.8125
Epoch 00017: saving model to /content/data/model/weights.epoch_17.hdf5
163/163 [==============================] - 89s 543ms/step - loss: 0.1070 -
acc: 0.9592 - val_loss: 0.3082 - val_acc: 0.8125
Epoch 18/100
162/163 [============================>.] - ETA: 0s - loss: 0.1105 - acc: 0
.9572Epoch 1/100
  1/163 [..............................] - ETA: 55s - loss: 0.3183 - acc:
0.8125
Epoch 00018: saving model to /content/data/model/weights.epoch_18.hdf5
163/163 [==============================] - 88s 542ms/step - loss: 0.1102 -
acc: 0.9572 - val_loss: 0.3183 - val_acc: 0.8125
Epoch 19/100
162/163 [============================>.] - ETA: 0s - loss: 0.1108 - acc: 0
.9599Epoch 1/100
  1/163 [..............................] - ETA: 59s - loss: 0.3411 - acc:
0.8125
Epoch 00019: saving model to /content/data/model/weights.epoch_19.hdf5
163/163 [==============================] - 89s 544ms/step - loss: 0.1105 -
acc: 0.9601 - val_loss: 0.3411 - val_acc: 0.8125
Epoch 20/100
162/163 [============================>.] - ETA: 0s - loss: 0.1047 - acc: 0
.9616Epoch 1/100
  1/163 [..............................] - ETA: 56s - loss: 0.3619 - acc:
0.7500
Epoch 00020: saving model to /content/data/model/weights.epoch_20.hdf5
163/163 [==============================] - 88s 540ms/step - loss: 0.1048 -
acc: 0.9613 - val_loss: 0.3619 - val_acc: 0.7500
Epoch 21/100
162/163 [============================>.] - ETA: 0s - loss: 0.1104 - acc: 0
.9595Epoch 1/100
  1/163 [..............................] - ETA: 56s - loss: 0.3417 - acc:
0.8125
Epoch 00021: saving model to /content/data/model/weights.epoch_21.hdf5
163/163 [==============================] - 88s 542ms/step - loss: 0.1099 -
acc: 0.9597 - val_loss: 0.3417 - val_acc: 0.8125
Epoch 22/100
162/163 [============================>.] - ETA: 0s - loss: 0.1037 - acc: 0
.9637Epoch 1/100
  1/163 [..............................] - ETA: 56s - loss: 0.2823 - acc:
0.8125
Epoch 00022: saving model to /content/data/model/weights.epoch_22.hdf5
163/163 [==============================] - 89s 545ms/step - loss: 0.1036 -
acc: 0.9638 - val_loss: 0.2823 - val_acc: 0.8125
Epoch 23/100
162/163 [============================>.] - ETA: 0s - loss: 0.1043 - acc: 0
.9626Epoch 1/100
  1/163 [..............................] - ETA: 59s - loss: 0.3080 - acc:
```

```
0.8125
Epoch 00023: saving model to /content/data/model/weights.epoch_23.hdf5
163/163 [==============================] - 89s 544ms/step - loss: 0.1042 -
acc: 0.9626 - val_loss: 0.3080 - val_acc: 0.8125
Epoch 24/100
162/163 [============================>.] - ETA: 0s - loss: 0.1009 - acc: 0
.9622Epoch 1/100
  1/163 [..............................] - ETA: 58s - loss: 0.3542 - acc:
0.8125
Epoch 00024: saving model to /content/data/model/weights.epoch_24.hdf5
163/163 [==============================] - 88s 542ms/step - loss: 0.1010 -
acc: 0.9622 - val_loss: 0.3542 - val_acc: 0.8125
Epoch 25/100
162/163 [============================>.] - ETA: 0s - loss: 0.1023 - acc: 0
.9635Epoch 1/100
  1/163 [..............................] - ETA: 56s - loss: 0.3132 - acc:
0.8125
Epoch 00025: saving model to /content/data/model/weights.epoch_25.hdf5
163/163 [==============================] - 88s 539ms/step - loss: 0.1022 -
acc: 0.9638 - val_loss: 0.3132 - val_acc: 0.8125
Epoch 26/100
162/163 [============================>.] - ETA: 0s - loss: 0.1046 - acc: 0
.9610Epoch 1/100
  1/163 [..............................] - ETA: 55s - loss: 0.3176 - acc:
0.8125
Epoch 00026: saving model to /content/data/model/weights.epoch_26.hdf5
163/163 [==============================] - 88s 541ms/step - loss: 0.1044 -
acc: 0.9611 - val_loss: 0.3176 - val_acc: 0.8125
Epoch 27/100
162/163 [============================>.] - ETA: 0s - loss: 0.0994 - acc: 0
.9633Epoch 1/100
  1/163 [..............................] - ETA: 56s - loss: 0.3416 - acc:
0.8125
Epoch 00027: saving model to /content/data/model/weights.epoch_27.hdf5
163/163 [==============================] - 89s 546ms/step - loss: 0.0991 -
acc: 0.9636 - val_loss: 0.3416 - val_acc: 0.8125
Epoch 28/100
162/163 [============================>.] - ETA: 0s - loss: 0.0975 - acc: 0
.9641Epoch 1/100
  1/163 [..............................] - ETA: 57s - loss: 0.2867 - acc:
0.8125
Epoch 00028: saving model to /content/data/model/weights.epoch_28.hdf5
163/163 [==============================] - 88s 538ms/step - loss: 0.0970 -
acc: 0.9643 - val_loss: 0.2867 - val_acc: 0.8125
Epoch 29/100
162/163 [============================>.] - ETA: 0s - loss: 0.1019 - acc: 0
.9624Epoch 1/100
  1/163 [..............................] - ETA: 54s - loss: 0.2479 - acc:
0.8125
Epoch 00029: saving model to /content/data/model/weights.epoch_29.hdf5
163/163 [==============================] - 88s 538ms/step - loss: 0.1023 -
acc: 0.9622 - val_loss: 0.2479 - val_acc: 0.8125
Epoch 30/100
162/163 [============================>.] - ETA: 0s - loss: 0.0962 - acc: 0
```

```
.9651Epoch 1/100
  1/163 [..............................] - ETA: 57s - loss: 0.2451 - acc:
0.8125
Epoch 00030: saving model to /content/data/model/weights.epoch_30.hdf5
163/163 [==============================] - 89s 544ms/step - loss: 0.0974 -
acc: 0.9647 - val_loss: 0.2451 - val_acc: 0.8125
Epoch 31/100
162/163 [============================>.] - ETA: 0s - loss: 0.0977 - acc: 0
.9660Epoch 1/100
  1/163 [..............................] - ETA: 55s - loss: 0.3205 - acc:
0.8125
Epoch 00031: saving model to /content/data/model/weights.epoch_31.hdf5
163/163 [==============================] - 89s 548ms/step - loss: 0.0979 -
acc: 0.9659 - val_loss: 0.3205 - val_acc: 0.8125
Epoch 32/100
162/163 [============================>.] - ETA: 0s - loss: 0.0947 - acc: 0
.9649Epoch 1/100
  1/163 [..............................] - ETA: 55s - loss: 0.3161 - acc:
0.8125
Epoch 00032: saving model to /content/data/model/weights.epoch_32.hdf5
163/163 [==============================] - 88s 541ms/step - loss: 0.0950 -
acc: 0.9649 - val_loss: 0.3161 - val_acc: 0.8125
Epoch 33/100
162/163 [============================>.] - ETA: 0s - loss: 0.0967 - acc: 0
.9635Epoch 1/100
  1/163 [..............................] - ETA: 57s - loss: 0.2692 - acc:
0.8125
Epoch 00033: saving model to /content/data/model/weights.epoch_33.hdf5
163/163 [==============================] - 89s 545ms/step - loss: 0.0965 -
acc: 0.9636 - val_loss: 0.2692 - val_acc: 0.8125
Epoch 34/100
162/163 [============================>.] - ETA: 0s - loss: 0.0919 - acc: 0
.9684Epoch 1/100
  1/163 [..............................] - ETA: 55s - loss: 0.3103 - acc:
0.8750
Epoch 00034: saving model to /content/data/model/weights.epoch_34.hdf5
163/163 [==============================] - 89s 544ms/step - loss: 0.0918 -
acc: 0.9684 - val_loss: 0.3103 - val_acc: 0.8750
Epoch 35/100
162/163 [============================>.] - ETA: 0s - loss: 0.0893 - acc: 0
.9678Epoch 1/100
  1/163 [..............................] - ETA: 57s - loss: 0.2456 - acc:
0.8125
Epoch 00035: saving model to /content/data/model/weights.epoch_35.hdf5
163/163 [==============================] - 88s 542ms/step - loss: 0.0896 -
acc: 0.9674 - val_loss: 0.2456 - val_acc: 0.8125
Epoch 36/100
162/163 [============================>.] - ETA: 0s - loss: 0.0918 - acc: 0
.9674Epoch 1/100
  1/163 [..............................] - ETA: 57s - loss: 0.2315 - acc:
0.8125
Epoch 00036: saving model to /content/data/model/weights.epoch_36.hdf5
163/163 [==============================] - 86s 530ms/step - loss: 0.0916 -
acc: 0.9674 - val_loss: 0.2315 - val_acc: 0.8125
```

```
Epoch 37/100
162/163 [============================>.] - ETA: 0s - loss: 0.0943 - acc: 0
.9662Epoch 1/100
  1/163 [..............................] - ETA: 55s - loss: 0.2523 - acc:
0.8125
Epoch 00037: saving model to /content/data/model/weights.epoch_37.hdf5
163/163 [==============================] - 88s 541ms/step - loss: 0.0943 -
acc: 0.9661 - val_loss: 0.2523 - val_acc: 0.8125
Epoch 38/100
162/163 [============================>.] - ETA: 0s - loss: 0.0912 - acc: 0
.9672Epoch 1/100
  1/163 [..............................] - ETA: 55s - loss: 0.3171 - acc:
0.8750
Epoch 00038: saving model to /content/data/model/weights.epoch_38.hdf5
163/163 [==============================] - 87s 537ms/step - loss: 0.0911 -
acc: 0.9670 - val_loss: 0.3171 - val_acc: 0.8750
Epoch 39/100
162/163 [============================>.] - ETA: 0s - loss: 0.0961 - acc: 0
.9641Epoch 1/100
  1/163 [..............................] - ETA: 55s - loss: 0.2345 - acc:
0.8125
Epoch 00039: saving model to /content/data/model/weights.epoch_39.hdf5
163/163 [==============================] - 87s 533ms/step - loss: 0.0961 -
acc: 0.9640 - val_loss: 0.2345 - val_acc: 0.8125
Epoch 40/100
162/163 [============================>.] - ETA: 0s - loss: 0.0921 - acc: 0
.9655Epoch 1/100
  1/163 [..............................] - ETA: 55s - loss: 0.2193 - acc:
0.8125
Epoch 00040: saving model to /content/data/model/weights.epoch_40.hdf5
163/163 [==============================] - 86s 528ms/step - loss: 0.0926 -
acc: 0.9653 - val_loss: 0.2193 - val_acc: 0.8125
Epoch 41/100
162/163 [============================>.] - ETA: 0s - loss: 0.0928 - acc: 0
.9674Epoch 1/100
  1/163 [..............................] - ETA: 55s - loss: 0.2287 - acc:
0.8125
Epoch 00041: saving model to /content/data/model/weights.epoch_41.hdf5
163/163 [==============================] - 87s 531ms/step - loss: 0.0924 -
acc: 0.9676 - val_loss: 0.2287 - val_acc: 0.8125
Epoch 42/100
162/163 [============================>.] - ETA: 0s - loss: 0.0900 - acc: 0
.9678Epoch 1/100
  1/163 [..............................] - ETA: 53s - loss: 0.2158 - acc:
0.8125
Epoch 00042: saving model to /content/data/model/weights.epoch_42.hdf5
163/163 [==============================] - 87s 533ms/step - loss: 0.0899 -
acc: 0.9678 - val_loss: 0.2158 - val_acc: 0.8125
Epoch 43/100
162/163 [============================>.] - ETA: 0s - loss: 0.0892 - acc: 0
.9637Epoch 1/100
  1/163 [..............................] - ETA: 57s - loss: 0.2131 - acc:
0.8125
Epoch 00043: saving model to /content/data/model/weights.epoch_43.hdf5
```

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163/163 [==============================] - 88s 537ms/step - loss: 0.0890 -
acc: 0.9640 - val_loss: 0.2131 - val_acc: 0.8125
Epoch 44/100
162/163 [============================>.] - ETA: 0s - loss: 0.0929 - acc: 0
.9666Epoch 1/100
  1/163 [..............................] - ETA: 57s - loss: 0.3028 - acc:
0.8750
Epoch 00044: saving model to /content/data/model/weights.epoch_44.hdf5
163/163 [==============================] - 90s 552ms/step - loss: 0.0929 -
acc: 0.9666 - val_loss: 0.3028 - val_acc: 0.8750
Epoch 45/100
162/163 [============================>.] - ETA: 0s - loss: 0.0895 - acc: 0
.9672Epoch 1/100
  1/163 [..............................] - ETA: 54s - loss: 0.2456 - acc:
0.8125
Epoch 00045: saving model to /content/data/model/weights.epoch_45.hdf5
163/163 [==============================] - 89s 549ms/step - loss: 0.0892 -
acc: 0.9674 - val_loss: 0.2456 - val_acc: 0.8125
Epoch 46/100
162/163 [============================>.] - ETA: 0s - loss: 0.0890 - acc: 0
.9674Epoch 1/100
  1/163 [..............................] - ETA: 53s - loss: 0.2400 - acc:
0.8125
Epoch 00046: saving model to /content/data/model/weights.epoch_46.hdf5
163/163 [==============================] - 90s 552ms/step - loss: 0.0895 -
acc: 0.9672 - val_loss: 0.2400 - val_acc: 0.8125
Epoch 47/100
162/163 [============================>.] - ETA: 0s - loss: 0.0862 - acc: 0
.9705Epoch 1/100
  1/163 [..............................] - ETA: 57s - loss: 0.2124 - acc:
0.8125
Epoch 00047: saving model to /content/data/model/weights.epoch_47.hdf5
163/163 [==============================] - 89s 549ms/step - loss: 0.0873 -
acc: 0.9701 - val_loss: 0.2124 - val_acc: 0.8125
Epoch 48/100
162/163 [============================>.] - ETA: 0s - loss: 0.0884 - acc: 0
.9678Epoch 1/100
  1/163 [..............................] - ETA: 55s - loss: 0.2080 - acc:
0.8125
Epoch 00048: saving model to /content/data/model/weights.epoch_48.hdf5
163/163 [==============================] - 90s 554ms/step - loss: 0.0883 -
acc: 0.9678 - val_loss: 0.2080 - val_acc: 0.8125
Epoch 49/100
162/163 [============================>.] - ETA: 0s - loss: 0.0885 - acc: 0
.9668Epoch 1/100
  1/163 [..............................] - ETA: 56s - loss: 0.2150 - acc:
0.8125
Epoch 00049: saving model to /content/data/model/weights.epoch_49.hdf5
163/163 [==============================] - 89s 544ms/step - loss: 0.0883 -
acc: 0.9670 - val_loss: 0.2150 - val_acc: 0.8125
Epoch 50/100
162/163 [============================>.] - ETA: 0s - loss: 0.0850 - acc: 0
.9684Epoch 1/100
  1/163 [..............................] - ETA: 54s - loss: 0.1961 - acc:
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0.8750
Epoch 00050: saving model to /content/data/model/weights.epoch_50.hdf5
163/163 [==============================] - 89s 545ms/step - loss: 0.0850 -
acc: 0.9684 - val_loss: 0.1961 - val_acc: 0.8750
Epoch 51/100
162/163 [============================>.] - ETA: 0s - loss: 0.0846 - acc: 0
.9697Epoch 1/100
  1/163 [..............................] - ETA: 54s - loss: 0.2380 - acc:
0.8125
Epoch 00051: saving model to /content/data/model/weights.epoch_51.hdf5
163/163 [==============================] - 88s 543ms/step - loss: 0.0842 -
acc: 0.9699 - val_loss: 0.2380 - val_acc: 0.8125
Epoch 52/100
162/163 [============================>.] - ETA: 0s - loss: 0.0855 - acc: 0
.9684Epoch 1/100
  1/163 [..............................] - ETA: 57s - loss: 0.2118 - acc:
0.8125
Epoch 00052: saving model to /content/data/model/weights.epoch_52.hdf5
163/163 [==============================] - 89s 544ms/step - loss: 0.0853 -
acc: 0.9684 - val_loss: 0.2118 - val_acc: 0.8125
Epoch 53/100
162/163 [============================>.] - ETA: 0s - loss: 0.0874 - acc: 0
.9689Epoch 1/100
  1/163 [..............................] - ETA: 54s - loss: 0.2553 - acc:
0.8750
Epoch 00053: saving model to /content/data/model/weights.epoch_53.hdf5
163/163 [==============================] - 89s 548ms/step - loss: 0.0873 -
acc: 0.9689 - val_loss: 0.2553 - val_acc: 0.8750
Epoch 54/100
162/163 [============================>.] - ETA: 0s - loss: 0.0849 - acc: 0
.9697Epoch 1/100
  1/163 [..............................] - ETA: 57s - loss: 0.1868 - acc:
0.9375
Epoch 00054: saving model to /content/data/model/weights.epoch_54.hdf5
163/163 [==============================] - 88s 542ms/step - loss: 0.0848 -
acc: 0.9697 - val_loss: 0.1868 - val_acc: 0.9375
Epoch 55/100
162/163 [============================>.] - ETA: 0s - loss: 0.0905 - acc: 0
.9674Epoch 1/100
  1/163 [..............................] - ETA: 56s - loss: 0.2085 - acc:
0.8125
Epoch 00055: saving model to /content/data/model/weights.epoch_55.hdf5
163/163 [==============================] - 90s 552ms/step - loss: 0.0903 -
acc: 0.9674 - val_loss: 0.2085 - val_acc: 0.8125
Epoch 56/100
162/163 [============================>.] - ETA: 0s - loss: 0.0861 - acc: 0
.9684Epoch 1/100
  1/163 [..............................] - ETA: 56s - loss: 0.2242 - acc:
0.8125
Epoch 00056: saving model to /content/data/model/weights.epoch_56.hdf5
163/163 [==============================] - 88s 541ms/step - loss: 0.0865 -
acc: 0.9682 - val_loss: 0.2242 - val_acc: 0.8125
Epoch 57/100
162/163 [============================>.] - ETA: 0s - loss: 0.0847 - acc: 0
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.9682Epoch 1/100
  1/163 [..............................] - ETA: 58s - loss: 0.2123 - acc:
0.8125
Epoch 00057: saving model to /content/data/model/weights.epoch_57.hdf5
163/163 [==============================] - 89s 544ms/step - loss: 0.0844 -
acc: 0.9684 - val_loss: 0.2123 - val_acc: 0.8125
Epoch 58/100
162/163 [============================>.] - ETA: 0s - loss: 0.0840 - acc: 0
.9680Epoch 1/100
  1/163 [..............................] - ETA: 55s - loss: 0.1873 - acc:
0.9375
Epoch 00058: saving model to /content/data/model/weights.epoch_58.hdf5
163/163 [==============================] - 88s 538ms/step - loss: 0.0841 -
acc: 0.9680 - val_loss: 0.1873 - val_acc: 0.9375
Epoch 59/100
162/163 [============================>.] - ETA: 0s - loss: 0.0827 - acc: 0
.9666Epoch 1/100
  1/163 [..............................] - ETA: 53s - loss: 0.1869 - acc:
0.9375
Epoch 00059: saving model to /content/data/model/weights.epoch_59.hdf5
163/163 [==============================] - 86s 526ms/step - loss: 0.0830 -
acc: 0.9663 - val_loss: 0.1869 - val_acc: 0.9375
Epoch 60/100
162/163 [============================>.] - ETA: 0s - loss: 0.0830 - acc: 0
.9691Epoch 1/100
  1/163 [..............................] - ETA: 54s - loss: 0.1963 - acc:
0.8125
Epoch 00060: saving model to /content/data/model/weights.epoch_60.hdf5
163/163 [==============================] - 85s 523ms/step - loss: 0.0829 -
acc: 0.9691 - val_loss: 0.1963 - val_acc: 0.8125
Epoch 61/100
162/163 [============================>.] - ETA: 0s - loss: 0.0825 - acc: 0
.9709Epoch 1/100
  1/163 [..............................] - ETA: 54s - loss: 0.1639 - acc:
0.9375
Epoch 00061: saving model to /content/data/model/weights.epoch_61.hdf5
163/163 [==============================] - 85s 521ms/step - loss: 0.0826 -
acc: 0.9709 - val_loss: 0.1639 - val_acc: 0.9375
Epoch 62/100
162/163 [============================>.] - ETA: 0s - loss: 0.0782 - acc: 0
.9701Epoch 1/100
  1/163 [..............................] - ETA: 55s - loss: 0.2110 - acc:
0.8750
Epoch 00062: saving model to /content/data/model/weights.epoch_62.hdf5
163/163 [==============================] - 85s 519ms/step - loss: 0.0780 -
acc: 0.9703 - val_loss: 0.2110 - val_acc: 0.8750
Epoch 63/100
162/163 [============================>.] - ETA: 0s - loss: 0.0808 - acc: 0
.9718Epoch 1/100
  1/163 [..............................] - ETA: 53s - loss: 0.1888 - acc:
0.8125
Epoch 00063: saving model to /content/data/model/weights.epoch_63.hdf5
163/163 [==============================] - 86s 526ms/step - loss: 0.0813 -
acc: 0.9714 - val_loss: 0.1888 - val_acc: 0.8125
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Epoch 64/100
162/163 [============================>.] - ETA: 0s - loss: 0.0796 - acc: 0
.9711Epoch 1/100
  1/163 [..............................] - ETA: 53s - loss: 0.2038 - acc:
0.8125
Epoch 00064: saving model to /content/data/model/weights.epoch_64.hdf5
163/163 [==============================] - 85s 521ms/step - loss: 0.0795 -
acc: 0.9711 - val_loss: 0.2038 - val_acc: 0.8125
Epoch 65/100
162/163 [============================>.] - ETA: 0s - loss: 0.0843 - acc: 0
.9701Epoch 1/100
  1/163 [..............................] - ETA: 55s - loss: 0.2073 - acc:
0.8125
Epoch 00065: saving model to /content/data/model/weights.epoch_65.hdf5
163/163 [==============================] - 86s 528ms/step - loss: 0.0841 -
acc: 0.9701 - val_loss: 0.2073 - val_acc: 0.8125
Epoch 66/100
162/163 [============================>.] - ETA: 0s - loss: 0.0782 - acc: 0
.9713Epoch 1/100
  1/163 [..............................] - ETA: 54s - loss: 0.2053 - acc:
0.8125
Epoch 00066: saving model to /content/data/model/weights.epoch_66.hdf5
163/163 [==============================] - 88s 540ms/step - loss: 0.0782 -
acc: 0.9712 - val_loss: 0.2053 - val_acc: 0.8125
Epoch 67/100
162/163 [============================>.] - ETA: 0s - loss: 0.0840 - acc: 0
.9697Epoch 1/100
  1/163 [..............................] - ETA: 57s - loss: 0.1979 - acc:
0.8125
Epoch 00067: saving model to /content/data/model/weights.epoch_67.hdf5
163/163 [==============================] - 88s 539ms/step - loss: 0.0838 -
acc: 0.9699 - val_loss: 0.1979 - val_acc: 0.8125
Epoch 68/100
162/163 [============================>.] - ETA: 0s - loss: 0.0815 - acc: 0
.9678Epoch 1/100
  1/163 [..............................] - ETA: 57s - loss: 0.1879 - acc:
0.8125
Epoch 00068: saving model to /content/data/model/weights.epoch_68.hdf5
163/163 [==============================] - 86s 531ms/step - loss: 0.0818 -
acc: 0.9676 - val_loss: 0.1879 - val_acc: 0.8125
Epoch 69/100
162/163 [============================>.] - ETA: 0s - loss: 0.0845 - acc: 0
.9691Epoch 1/100
  1/163 [..............................] - ETA: 56s - loss: 0.2327 - acc:
0.8750
Epoch 00069: saving model to /content/data/model/weights.epoch_69.hdf5
163/163 [==============================] - 88s 538ms/step - loss: 0.0842 -
acc: 0.9693 - val_loss: 0.2327 - val_acc: 0.8750
Epoch 70/100
162/163 [============================>.] - ETA: 0s - loss: 0.0863 - acc: 0
.9680Epoch 1/100
  1/163 [..............................] - ETA: 54s - loss: 0.2164 - acc:
0.8750
Epoch 00070: saving model to /content/data/model/weights.epoch_70.hdf5
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163/163 [==============================] - 87s 532ms/step - loss: 0.0860 -
acc: 0.9680 - val_loss: 0.2164 - val_acc: 0.8750
Epoch 71/100
162/163 [============================>.] - ETA: 0s - loss: 0.0872 - acc: 0
.9676Epoch 1/100
  1/163 [..............................] - ETA: 54s - loss: 0.1782 - acc:
0.9375
Epoch 00071: saving model to /content/data/model/weights.epoch_71.hdf5
163/163 [==============================] - 86s 530ms/step - loss: 0.0872 -
acc: 0.9674 - val_loss: 0.1782 - val_acc: 0.9375
Epoch 72/100
162/163 [============================>.] - ETA: 0s - loss: 0.0840 - acc: 0
.9680Epoch 1/100
  1/163 [..............................] - ETA: 1:00 - loss: 0.2230 - acc:
0.8750
Epoch 00072: saving model to /content/data/model/weights.epoch_72.hdf5
163/163 [==============================] - 87s 533ms/step - loss: 0.0839 -
acc: 0.9680 - val_loss: 0.2230 - val_acc: 0.8750
Epoch 73/100
162/163 [============================>.] - ETA: 0s - loss: 0.0766 - acc: 0
.9728Epoch 1/100
  1/163 [..............................] - ETA: 59s - loss: 0.2061 - acc:
0.8750
Epoch 00073: saving model to /content/data/model/weights.epoch_73.hdf5
163/163 [==============================] - 88s 538ms/step - loss: 0.0765 -
acc: 0.9728 - val_loss: 0.2061 - val_acc: 0.8750
Epoch 74/100
162/163 [============================>.] - ETA: 0s - loss: 0.0787 - acc: 0
.9718Epoch 1/100
  1/163 [..............................] - ETA: 56s - loss: 0.1594 - acc:
0.9375
Epoch 00074: saving model to /content/data/model/weights.epoch_74.hdf5
163/163 [==============================] - 87s 531ms/step - loss: 0.0787 -
acc: 0.9718 - val_loss: 0.1594 - val_acc: 0.9375
Epoch 75/100
162/163 [============================>.] - ETA: 0s - loss: 0.0760 - acc: 0
.9747Epoch 1/100
  1/163 [..............................] - ETA: 54s - loss: 0.1627 - acc:
0.9375
Epoch 00075: saving model to /content/data/model/weights.epoch_75.hdf5
163/163 [==============================] - 87s 533ms/step - loss: 0.0758 -
acc: 0.9749 - val_loss: 0.1627 - val_acc: 0.9375
Epoch 76/100
162/163 [============================>.] - ETA: 0s - loss: 0.0747 - acc: 0
.9732Epoch 1/100
  1/163 [..............................] - ETA: 54s - loss: 0.1986 - acc:
0.8750
Epoch 00076: saving model to /content/data/model/weights.epoch_76.hdf5
163/163 [==============================] - 87s 535ms/step - loss: 0.0751 -
acc: 0.9730 - val_loss: 0.1986 - val_acc: 0.8750
Epoch 77/100
162/163 [============================>.] - ETA: 0s - loss: 0.0768 - acc: 0
.9734Epoch 1/100
  1/163 [..............................] - ETA: 53s - loss: 0.1463 - acc:
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0.9375
Epoch 00077: saving model to /content/data/model/weights.epoch_77.hdf5
163/163 [==============================] - 87s 531ms/step - loss: 0.0768 -
acc: 0.9732 - val_loss: 0.1463 - val_acc: 0.9375
Epoch 78/100
162/163 [============================>.] - ETA: 0s - loss: 0.0763 - acc: 0
.9705Epoch 1/100
  1/163 [..............................] - ETA: 55s - loss: 0.1587 - acc:
0.9375
Epoch 00078: saving model to /content/data/model/weights.epoch_78.hdf5
163/163 [==============================] - 86s 529ms/step - loss: 0.0761 -
acc: 0.9705 - val_loss: 0.1587 - val_acc: 0.9375
Epoch 79/100
162/163 [============================>.] - ETA: 0s - loss: 0.0771 - acc: 0
.9718Epoch 1/100
  1/163 [..............................] - ETA: 55s - loss: 0.1669 - acc:
1.0000
Epoch 00079: saving model to /content/data/model/weights.epoch_79.hdf5
163/163 [==============================] - 87s 531ms/step - loss: 0.0768 -
acc: 0.9720 - val_loss: 0.1669 - val_acc: 1.0000
Epoch 80/100
162/163 [============================>.] - ETA: 0s - loss: 0.0781 - acc: 0
.9734Epoch 1/100
  1/163 [..............................] - ETA: 55s - loss: 0.1781 - acc:
0.8750
Epoch 00080: saving model to /content/data/model/weights.epoch_80.hdf5
163/163 [==============================] - 88s 537ms/step - loss: 0.0779 -
acc: 0.9734 - val_loss: 0.1781 - val_acc: 0.8750
Epoch 81/100
162/163 [============================>.] - ETA: 0s - loss: 0.0762 - acc: 0
.9740Epoch 1/100
  1/163 [..............................] - ETA: 54s - loss: 0.1641 - acc:
1.0000
Epoch 00081: saving model to /content/data/model/weights.epoch_81.hdf5
163/163 [==============================] - 87s 535ms/step - loss: 0.0761 -
acc: 0.9741 - val_loss: 0.1641 - val_acc: 1.0000
Epoch 82/100
162/163 [============================>.] - ETA: 0s - loss: 0.0725 - acc: 0
.9728Epoch 1/100
  1/163 [..............................] - ETA: 54s - loss: 0.1418 - acc:
0.9375
Epoch 00082: saving model to /content/data/model/weights.epoch_82.hdf5
163/163 [==============================] - 87s 536ms/step - loss: 0.0729 -
acc: 0.9728 - val_loss: 0.1418 - val_acc: 0.9375
Epoch 83/100
162/163 [============================>.] - ETA: 0s - loss: 0.0790 - acc: 0
.9697Epoch 1/100
  1/163 [..............................] - ETA: 54s - loss: 0.1629 - acc:
1.0000
Epoch 00083: saving model to /content/data/model/weights.epoch_83.hdf5
163/163 [==============================] - 87s 535ms/step - loss: 0.0789 -
acc: 0.9697 - val_loss: 0.1629 - val_acc: 1.0000
Epoch 84/100
162/163 [============================>.] - ETA: 0s - loss: 0.0811 - acc: 0
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.9697Epoch 1/100
  1/163 [..............................] - ETA: 56s - loss: 0.1452 - acc:
0.9375
Epoch 00084: saving model to /content/data/model/weights.epoch_84.hdf5
163/163 [==============================] - 87s 536ms/step - loss: 0.0807 -
acc: 0.9699 - val_loss: 0.1452 - val_acc: 0.9375
Epoch 85/100
162/163 [============================>.] - ETA: 0s - loss: 0.0756 - acc: 0
.9751Epoch 1/100
  1/163 [..............................] - ETA: 56s - loss: 0.1480 - acc:
1.0000
Epoch 00085: saving model to /content/data/model/weights.epoch_85.hdf5
163/163 [==============================] - 87s 534ms/step - loss: 0.0754 -
acc: 0.9751 - val_loss: 0.1480 - val_acc: 1.0000
Epoch 86/100
162/163 [============================>.] - ETA: 0s - loss: 0.0709 - acc: 0
.9726Epoch 1/100
  1/163 [..............................] - ETA: 55s - loss: 0.1407 - acc:
0.9375
Epoch 00086: saving model to /content/data/model/weights.epoch_86.hdf5
163/163 [==============================] - 87s 537ms/step - loss: 0.0712 -
acc: 0.9726 - val_loss: 0.1407 - val_acc: 0.9375
Epoch 87/100
162/163 [============================>.] - ETA: 0s - loss: 0.0786 - acc: 0
.9699Epoch 1/100
  1/163 [..............................] - ETA: 55s - loss: 0.1736 - acc:
0.8750
Epoch 00087: saving model to /content/data/model/weights.epoch_87.hdf5
163/163 [==============================] - 88s 537ms/step - loss: 0.0791 -
acc: 0.9699 - val_loss: 0.1736 - val_acc: 0.8750
Epoch 88/100
162/163 [============================>.] - ETA: 0s - loss: 0.0781 - acc: 0
.9716Epoch 1/100
  1/163 [..............................] - ETA: 55s - loss: 0.1542 - acc:
1.0000
Epoch 00088: saving model to /content/data/model/weights.epoch_88.hdf5
163/163 [==============================] - 87s 534ms/step - loss: 0.0782 -
acc: 0.9716 - val_loss: 0.1542 - val_acc: 1.0000
Epoch 89/100
162/163 [============================>.] - ETA: 0s - loss: 0.0802 - acc: 0
.9693Epoch 1/100
  1/163 [..............................] - ETA: 54s - loss: 0.2036 - acc:
0.8750
Epoch 00089: saving model to /content/data/model/weights.epoch_89.hdf5
163/163 [==============================] - 87s 536ms/step - loss: 0.0800 -
acc: 0.9695 - val_loss: 0.2036 - val_acc: 0.8750
Epoch 90/100
162/163 [============================>.] - ETA: 0s - loss: 0.0783 - acc: 0
.9705Epoch 1/100
  1/163 [..............................] - ETA: 56s - loss: 0.1412 - acc:
0.9375
Epoch 00090: saving model to /content/data/model/weights.epoch_90.hdf5
163/163 [==============================] - 87s 532ms/step - loss: 0.0780 -
acc: 0.9707 - val_loss: 0.1412 - val_acc: 0.9375
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Epoch 91/100
162/163 [============================>.] - ETA: 0s - loss: 0.0759 - acc: 0
.9730Epoch 1/100
  1/163 [..............................] - ETA: 54s - loss: 0.1327 - acc:
0.9375
Epoch 00091: saving model to /content/data/model/weights.epoch_91.hdf5
163/163 [==============================] - 87s 537ms/step - loss: 0.0762 -
acc: 0.9728 - val_loss: 0.1327 - val_acc: 0.9375
Epoch 92/100
162/163 [============================>.] - ETA: 0s - loss: 0.0770 - acc: 0
.9745Epoch 1/100
  1/163 [..............................] - ETA: 55s - loss: 0.1467 - acc:
1.0000
Epoch 00092: saving model to /content/data/model/weights.epoch_92.hdf5
163/163 [==============================] - 87s 531ms/step - loss: 0.0770 -
acc: 0.9745 - val_loss: 0.1467 - val_acc: 1.0000
Epoch 93/100
162/163 [============================>.] - ETA: 0s - loss: 0.0721 - acc: 0
.9730Epoch 1/100
  1/163 [..............................] - ETA: 57s - loss: 0.1429 - acc:
1.0000
Epoch 00093: saving model to /content/data/model/weights.epoch_93.hdf5
163/163 [==============================] - 87s 536ms/step - loss: 0.0722 -
acc: 0.9728 - val_loss: 0.1429 - val_acc: 1.0000
Epoch 94/100
162/163 [============================>.] - ETA: 0s - loss: 0.0762 - acc: 0
.9738Epoch 1/100
  1/163 [..............................] - ETA: 55s - loss: 0.1459 - acc:
1.0000
Epoch 00094: saving model to /content/data/model/weights.epoch_94.hdf5
163/163 [==============================] - 88s 539ms/step - loss: 0.0763 -
acc: 0.9735 - val_loss: 0.1459 - val_acc: 1.0000
Epoch 95/100
162/163 [============================>.] - ETA: 0s - loss: 0.0737 - acc: 0
.9728Epoch 1/100
  1/163 [..............................] - ETA: 55s - loss: 0.1659 - acc:
1.0000
Epoch 00095: saving model to /content/data/model/weights.epoch_95.hdf5
163/163 [==============================] - 87s 533ms/step - loss: 0.0741 -
acc: 0.9726 - val_loss: 0.1659 - val_acc: 1.0000
Epoch 96/100
162/163 [============================>.] - ETA: 0s - loss: 0.0722 - acc: 0
.9742Epoch 1/100
  1/163 [..............................] - ETA: 54s - loss: 0.1701 - acc:
0.9375
Epoch 00096: saving model to /content/data/model/weights.epoch_96.hdf5
163/163 [==============================] - 87s 532ms/step - loss: 0.0727 -
acc: 0.9739 - val_loss: 0.1701 - val_acc: 0.9375
Epoch 97/100
162/163 [============================>.] - ETA: 0s - loss: 0.0745 - acc: 0
.9732Epoch 1/100
  1/163 [..............................] - ETA: 56s - loss: 0.1706 - acc:
0.8750
Epoch 00097: saving model to /content/data/model/weights.epoch_97.hdf5
```

```
163/163 [==============================] - 87s 536ms/step - loss: 0.0745 -
acc: 0.9732 - val_loss: 0.1706 - val_acc: 0.8750
Epoch 98/100
162/163 [============================>.] - ETA: 0s - loss: 0.0720 - acc: 0
.9738Epoch 1/100
  1/163 [..............................] - ETA: 56s - loss: 0.1294 - acc:
0.9375
Epoch 00098: saving model to /content/data/model/weights.epoch_98.hdf5
163/163 [==============================] - 89s 544ms/step - loss: 0.0717 -
acc: 0.9739 - val_loss: 0.1294 - val_acc: 0.9375
Epoch 99/100
162/163 [============================>.] - ETA: 0s - loss: 0.0727 - acc: 0
.9716Epoch 1/100
  1/163 [..............................] - ETA: 56s - loss: 0.1350 - acc:
1.0000
Epoch 00099: saving model to /content/data/model/weights.epoch_99.hdf5
163/163 [==============================] - 88s 539ms/step - loss: 0.0728 -
acc: 0.9714 - val_loss: 0.1350 - val_acc: 1.0000
Epoch 100/100
162/163 [============================>.] - ETA: 0s - loss: 0.0751 - acc: 0
.9743Epoch 1/100
  1/163 [..............................] - ETA: 55s - loss: 0.1370 - acc:
1.0000
Epoch 00100: saving model to /content/data/model/weights.epoch_100.hdf5
163/163 [==============================] - 88s 541ms/step - loss: 0.0748 -
acc: 0.9745 - val_loss: 0.1370 - val_acc: 1.0000
```

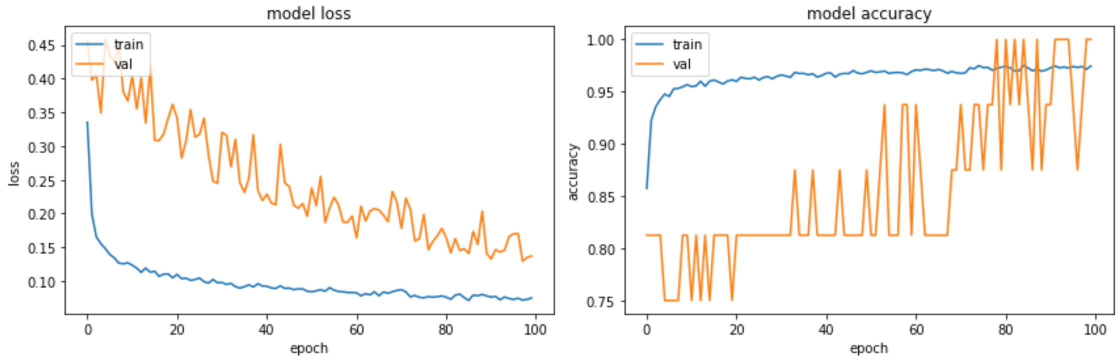
```
import matplotlib.pyplot as plt
def plot_learning_curves(history):
    plt.figure(figsize=(12,4))

    plt.subplot(1,2,1)
    plt.plot(history.history['loss'])
    plt.plot(history.history['val_loss'])
    plt.title('model loss')
    plt.ylabel('loss')
    plt.xlabel('epoch')
    plt.legend(['train', 'val'], loc='upper left')

    plt.subplot(1,2,2)
    plt.plot(history.history['acc'])
    plt.plot(history.history['val_acc'])
    plt.title('model accuracy')
    plt.ylabel('accuracy')
    plt.xlabel('epoch')
    plt.legend(['train', 'val'], loc='upper left')

    plt.tight_layout()

plot_learning_curves(history)
```



png

```
idx = np.argmin(history.history['val_loss'])
model.load_weights("/content/data/model/weights.epoch_{:02d}.hdf5".format(
idx + 1))

print("Loading the best model")
print("epoch: {}, val_loss: {}, val_acc: {}".format(idx + 1, history.histo
ry['val_loss'][idx], history.history['val_acc'][idx]))
```

```
Loading the best model
epoch: 98, val_loss: 0.1293676495552063, val_acc: 0.9375
```

```
test_loss, test_acc = model.evaluate_generator(generator=test_generator, v
erbose=1)
```

```
20/20 [==============================] - 7s 343ms/step - loss: 0.2117 - ac
c: 0.9247
```

```
from sklearn.metrics import accuracy_score, confusion_matrix

test_generator.reset()
test_preds = model.predict_generator(test_generator, verbose=1)
test_preds = np.argmax(test_preds,axis=1)

acc = accuracy_score(test_generator.classes, test_preds)*100
cm = confusion_matrix(test_generator.classes, test_preds)
tn, fp, fn, tp = cm.ravel()

print('CONFUSION MATRIX ------------------')
print(cm)
# plot_confusion_matrix(cm, target_names=['NORMAL', 'PNEUMONIA'], normaliz
e=False)


print('\nTEST METRICS ----------------------')
precision = tp/(tp+fp)*100
recall = tp/(tp+fn)*100
print('Accuracy: {}%'.format(acc))
print('Precision: {}%'.format(precision))
print('Recall: {}%'.format(recall))
print('F1-score: {}'.format(2*precision*recall/(precision+recall)))
```

```
print('\nTRAIN METRIC ----------------------')
print('Train acc: {}%'.format(np.round((history.history['acc'][-1])*100, 1
4)))
```

```
20/20 [==============================] - 7s 354ms/step
CONFUSION MATRIX ------------------
[[204  30]
 [ 17 373]]

TEST METRICS ----------------------
Accuracy: 92.46794871794873%
Precision: 92.55583126550869%
Recall: 95.64102564102565%
F1-score: 94.07313997477932

TRAIN METRIC ----------------------
Train acc: 97.45015501976015%
```

9.7 Appendix G: VGG16 Model 2 Version 2.1.1.0.0

```
from __future__ import absolute_import, division, print_function, unicode_
literals
import tensorflow as tf

# Extract dataset
import os
import tarfile

import keras_preprocessing
from keras_preprocessing.image import ImageDataGenerator # Data preprocess
ing and augmentation

import sklearn
import numpy as np

print(tf.__version__)

1.15.0

# Make folder for chest xray data
!mkdir /content/data/

# Make directory to save weights
!mkdir /content/data/model

# Make directory to logs for Tensorboard
!mkdir /content/data/graph

# Download dataset
!wget --no-check-certificate \
    https://s3.eu-central-1.amazonaws.com/public.unit8.co/data/chest_xray.
tar.gz \
    -O /content/data/chest_xray.tar.gz

tar = tarfile.open("data/chest_xray.tar.gz")
tar.extractall(path='./data/')
os.remove('data/chest_xray.tar.gz')

--2019-10-27 05:14:25--  https://s3.eu-central-1.amazonaws.com/public.unit
8.co/data/chest_xray.tar.gz
Resolving s3.eu-central-1.amazonaws.com (s3.eu-central-1.amazonaws.com)...
52.219.72.4
Connecting to s3.eu-central-1.amazonaws.com (s3.eu-central-1.amazonaws.com
)|52.219.72.4|:443... connected.
HTTP request sent, awaiting response... 200 OK
Length: 1225393795 (1.1G) [application/x-gzip]
Saving to: ‘/content/data/chest_xray.tar.gz’

/content/data/chest 100%[===================>]   1.14G  23.4MB/s    in 51s

2019-10-27 05:15:17 (22.8 MB/s) - ‘/content/data/chest_xray.tar.gz’ saved
[1225393795/1225393795]
```

Change log: > training_datagen –> ImageDataGenerator

trainable layer –> All except base

24 layers VGG16 model

Optimizer = RMSprop(learning_rate = 0.0001)

loss = categorical_crosscentropy

callback = [checkpoints]

epochs = 100

no class weight balancing

```
TRAINING_DIR = "/content/data/chest_xray/train"
VALIDATION_DIR = "/content/data/chest_xray/val"
TEST_DIR = "/content/data/chest_xray/test"

training_datagen = ImageDataGenerator(
    preprocessing_function=tf.keras.applications.vgg16.preprocess_input,
    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,
    # vertical_flip=True
    fill_mode='nearest'
)

validation_datagen = ImageDataGenerator(
    rescale = 1./255
)

test_datagen = ImageDataGenerator(
    rescale = 1./255
)

# Create training data batch
# TODO: Try grayscaling the image to see what will happen
train_generator = training_datagen.flow_from_directory(
    TRAINING_DIR,
    target_size=(150,150),
    class_mode='categorical'
)

validation_generator = validation_datagen.flow_from_directory(
    VALIDATION_DIR,
    target_size=(150,150),
    class_mode='categorical'
)

test_generator = test_datagen.flow_from_directory(
    TEST_DIR,
```

```
    target_size=(150,150),
    class_mode='categorical',
    shuffle=False
)

train_shape = train_generator.image_shape

tf.keras.backend.clear_session() # Destroys the current TF graph and creat
es a new one.

base_model = tf.keras.applications.VGG16(weights='imagenet', include_top=F
alse, input_shape=train_shape)

x = base_model.output
x = tf.keras.layers.Flatten()(x)
x = tf.keras.layers.Dense(64, activation='relu')(x)
x = tf.keras.layers.Dropout(0.33)(x)
x = tf.keras.layers.BatchNormalization()(x)
x = tf.keras.layers.Dense(2, 'softmax')(x)

model = tf.keras.Model(inputs=base_model.input, outputs=x)

# for layer in model.layers[0:20]:
#     layer.trainable = False

for layer in base_model.layers:
  layer.trainable = False

optimizer = tf.keras.optimizers.RMSprop(learning_rate=0.0001) # Lower lear
ning rate by x10

model.compile(loss='categorical_crossentropy',
              optimizer=optimizer,
              metrics=['accuracy'])

# Callbacks stuff
# Function to save the weights of the model after each epoch
checkpoint = tf.keras.callbacks.ModelCheckpoint(
    '/content/data/model/weights.epoch_{epoch:02d}.hdf5',
    monitor='val_accuracy',
    save_best_only=False,
    save_weights_only=False,
    mode='auto',
    verbose=1
)

# Function to stop training early if there's no improvement
early_stopping_monitor = tf.keras.callbacks.EarlyStopping(patience = 3, mo
nitor = "val_loss", mode="auto", verbose = 1)

lr_reduce = tf.keras.callbacks.ReduceLROnPlateau(monitor='val_loss', facto
r=0.3, patience=2, verbose=1, mode='max')

classweight = sklearn.utils.class_weight.compute_class_weight('balanced',
```

```
np.unique(train_generator.labels), train_generator.labels)
print(classweight)

batch_size = 32
epochs = 100

# Training process
history = model.fit_generator(
    generator=train_generator,
    # steps_per_epoch=train_generator.samples//batch_size,
    epochs=epochs,
    # callbacks=[early_stopping_monitor],
    callbacks=[checkpoint],
    # shuffle=True,
    validation_data=validation_generator,
    # validation_steps= validation_generator//batch_size, #no because it's
gonna be 0... if leave alone its len(generator) which is equal to 1.
    # class_weight=classweight,
    verbose = 1
)

# test_loss, test_acc = model.evaluate_generator(generator=test_generator,
verbose=1)
```

```
Found 5216 images belonging to 2 classes.
Found 16 images belonging to 2 classes.
Found 624 images belonging to 2 classes.
[1.9448173  0.67303226]
Epoch 1/100
162/163 [============================>.] - ETA: 0s - loss: 0.4086 - acc: 0
.8316Epoch 1/100
  1/163 [..............................] - ETA: 4:26 - loss: 0.3991 - acc:
0.8125
Epoch 00001: saving model to /content/data/model/weights.epoch_01.hdf5
163/163 [==============================] - 92s 563ms/step - loss: 0.4070 -
acc: 0.8322 - val_loss: 0.3991 - val_acc: 0.8125
Epoch 2/100
162/163 [============================>.] - ETA: 0s - loss: 0.2507 - acc: 0
.9271Epoch 1/100
  1/163 [..............................] - ETA: 54s - loss: 0.3287 - acc:
0.8125
Epoch 00002: saving model to /content/data/model/weights.epoch_02.hdf5
163/163 [==============================] - 85s 524ms/step - loss: 0.2505 -
acc: 0.9271 - val_loss: 0.3287 - val_acc: 0.8125
Epoch 3/100
162/163 [============================>.] - ETA: 0s - loss: 0.2063 - acc: 0
.9373Epoch 1/100
  1/163 [..............................] - ETA: 56s - loss: 0.2651 - acc:
0.8750
Epoch 00003: saving model to /content/data/model/weights.epoch_03.hdf5
163/163 [==============================] - 87s 532ms/step - loss: 0.2058 -
acc: 0.9375 - val_loss: 0.2651 - val_acc: 0.8750
Epoch 4/100
162/163 [============================>.] - ETA: 0s - loss: 0.1740 - acc: 0
```

```
.9460Epoch 1/100
  1/163 [..............................] - ETA: 57s - loss: 0.3186 - acc:
0.8125
Epoch 00004: saving model to /content/data/model/weights.epoch_04.hdf5
163/163 [==============================] - 87s 534ms/step - loss: 0.1734 -
acc: 0.9463 - val_loss: 0.3186 - val_acc: 0.8125
Epoch 5/100
162/163 [============================>.] - ETA: 0s - loss: 0.1643 - acc: 0
.9431Epoch 1/100
  1/163 [..............................] - ETA: 56s - loss: 0.3525 - acc:
0.8125
Epoch 00005: saving model to /content/data/model/weights.epoch_05.hdf5
163/163 [==============================] - 87s 536ms/step - loss: 0.1642 -
acc: 0.9429 - val_loss: 0.3525 - val_acc: 0.8125
Epoch 6/100
162/163 [============================>.] - ETA: 0s - loss: 0.1421 - acc: 0
.9498Epoch 1/100
  1/163 [..............................] - ETA: 57s - loss: 0.3826 - acc:
0.8125
Epoch 00006: saving model to /content/data/model/weights.epoch_06.hdf5
163/163 [==============================] - 88s 538ms/step - loss: 0.1426 -
acc: 0.9496 - val_loss: 0.3826 - val_acc: 0.8125
Epoch 7/100
162/163 [============================>.] - ETA: 0s - loss: 0.1485 - acc: 0
.9504Epoch 1/100
  1/163 [..............................] - ETA: 57s - loss: 0.3499 - acc:
0.8125
Epoch 00007: saving model to /content/data/model/weights.epoch_07.hdf5
163/163 [==============================] - 87s 536ms/step - loss: 0.1478 -
acc: 0.9507 - val_loss: 0.3499 - val_acc: 0.8125
Epoch 8/100
162/163 [============================>.] - ETA: 0s - loss: 0.1403 - acc: 0
.9510Epoch 1/100
  1/163 [..............................] - ETA: 57s - loss: 0.3228 - acc:
0.8750
Epoch 00008: saving model to /content/data/model/weights.epoch_08.hdf5
163/163 [==============================] - 88s 539ms/step - loss: 0.1412 -
acc: 0.9507 - val_loss: 0.3228 - val_acc: 0.8750
Epoch 9/100
162/163 [============================>.] - ETA: 0s - loss: 0.1461 - acc: 0
.9473Epoch 1/100
  1/163 [..............................] - ETA: 56s - loss: 0.2416 - acc:
0.8125
Epoch 00009: saving model to /content/data/model/weights.epoch_09.hdf5
163/163 [==============================] - 88s 537ms/step - loss: 0.1460 -
acc: 0.9473 - val_loss: 0.2416 - val_acc: 0.8125
Epoch 10/100
162/163 [============================>.] - ETA: 0s - loss: 0.1290 - acc: 0
.9527Epoch 1/100
  1/163 [..............................] - ETA: 57s - loss: 0.2749 - acc:
0.8750
Epoch 00010: saving model to /content/data/model/weights.epoch_10.hdf5
163/163 [==============================] - 88s 539ms/step - loss: 0.1288 -
acc: 0.9528 - val_loss: 0.2749 - val_acc: 0.8750
```

```
Epoch 11/100
162/163 [============================>.] - ETA: 0s - loss: 0.1317 - acc: 0
.9549Epoch 1/100
  1/163 [..............................] - ETA: 56s - loss: 0.4315 - acc:
0.7500
Epoch 00011: saving model to /content/data/model/weights.epoch_11.hdf5
163/163 [==============================] - 89s 547ms/step - loss: 0.1318 -
acc: 0.9548 - val_loss: 0.4315 - val_acc: 0.7500
Epoch 12/100
162/163 [============================>.] - ETA: 0s - loss: 0.1192 - acc: 0
.9581Epoch 1/100
  1/163 [..............................] - ETA: 59s - loss: 0.3953 - acc:
0.8125
Epoch 00012: saving model to /content/data/model/weights.epoch_12.hdf5
163/163 [==============================] - 89s 547ms/step - loss: 0.1189 -
acc: 0.9582 - val_loss: 0.3953 - val_acc: 0.8125
Epoch 13/100
162/163 [============================>.] - ETA: 0s - loss: 0.1210 - acc: 0
.9576Epoch 1/100
  1/163 [..............................] - ETA: 55s - loss: 0.2080 - acc:
0.8750
Epoch 00013: saving model to /content/data/model/weights.epoch_13.hdf5
163/163 [==============================] - 89s 545ms/step - loss: 0.1209 -
acc: 0.9576 - val_loss: 0.2080 - val_acc: 0.8750
Epoch 14/100
162/163 [============================>.] - ETA: 0s - loss: 0.1239 - acc: 0
.9545Epoch 1/100
  1/163 [..............................] - ETA: 56s - loss: 0.2700 - acc:
0.8750
Epoch 00014: saving model to /content/data/model/weights.epoch_14.hdf5
163/163 [==============================] - 88s 539ms/step - loss: 0.1240 -
acc: 0.9546 - val_loss: 0.2700 - val_acc: 0.8750
Epoch 15/100
162/163 [============================>.] - ETA: 0s - loss: 0.1191 - acc: 0
.9587Epoch 1/100
  1/163 [..............................] - ETA: 56s - loss: 0.4464 - acc:
0.7500
Epoch 00015: saving model to /content/data/model/weights.epoch_15.hdf5
163/163 [==============================] - 88s 538ms/step - loss: 0.1192 -
acc: 0.9586 - val_loss: 0.4464 - val_acc: 0.7500
Epoch 16/100
162/163 [============================>.] - ETA: 0s - loss: 0.1164 - acc: 0
.9591Epoch 1/100
  1/163 [..............................] - ETA: 53s - loss: 0.3760 - acc:
0.8125
Epoch 00016: saving model to /content/data/model/weights.epoch_16.hdf5
163/163 [==============================] - 85s 524ms/step - loss: 0.1174 -
acc: 0.9588 - val_loss: 0.3760 - val_acc: 0.8125
Epoch 17/100
162/163 [============================>.] - ETA: 0s - loss: 0.1126 - acc: 0
.9610Epoch 1/100
  1/163 [..............................] - ETA: 54s - loss: 0.3419 - acc:
0.8750
Epoch 00017: saving model to /content/data/model/weights.epoch_17.hdf5
```

```
163/163 [==============================] - 86s 528ms/step - loss: 0.1133 -
acc: 0.9605 - val_loss: 0.3419 - val_acc: 0.8750
Epoch 18/100
162/163 [============================>.] - ETA: 0s - loss: 0.1161 - acc: 0
.9585Epoch 1/100
  1/163 [..............................] - ETA: 55s - loss: 0.3383 - acc:
0.8750
Epoch 00018: saving model to /content/data/model/weights.epoch_18.hdf5
163/163 [==============================] - 88s 537ms/step - loss: 0.1158 -
acc: 0.9588 - val_loss: 0.3383 - val_acc: 0.8750
Epoch 19/100
162/163 [============================>.] - ETA: 0s - loss: 0.1165 - acc: 0
.9595Epoch 1/100
  1/163 [..............................] - ETA: 54s - loss: 0.2217 - acc:
0.8750
Epoch 00019: saving model to /content/data/model/weights.epoch_19.hdf5
163/163 [==============================] - 86s 530ms/step - loss: 0.1163 -
acc: 0.9595 - val_loss: 0.2217 - val_acc: 0.8750
Epoch 20/100
162/163 [============================>.] - ETA: 0s - loss: 0.1012 - acc: 0
.9633Epoch 1/100
  1/163 [..............................] - ETA: 54s - loss: 0.2163 - acc:
0.8750
Epoch 00020: saving model to /content/data/model/weights.epoch_20.hdf5
163/163 [==============================] - 86s 525ms/step - loss: 0.1023 -
acc: 0.9630 - val_loss: 0.2163 - val_acc: 0.8750
Epoch 21/100
162/163 [============================>.] - ETA: 0s - loss: 0.1058 - acc: 0
.9603Epoch 1/100
  1/163 [..............................] - ETA: 55s - loss: 0.1534 - acc:
0.9375
Epoch 00021: saving model to /content/data/model/weights.epoch_21.hdf5
163/163 [==============================] - 86s 525ms/step - loss: 0.1061 -
acc: 0.9599 - val_loss: 0.1534 - val_acc: 0.9375
Epoch 22/100
162/163 [============================>.] - ETA: 0s - loss: 0.1041 - acc: 0
.9628Epoch 1/100
  1/163 [..............................] - ETA: 55s - loss: 0.1989 - acc:
0.8750
Epoch 00022: saving model to /content/data/model/weights.epoch_22.hdf5
163/163 [==============================] - 88s 537ms/step - loss: 0.1038 -
acc: 0.9628 - val_loss: 0.1989 - val_acc: 0.8750
Epoch 23/100
162/163 [============================>.] - ETA: 0s - loss: 0.1014 - acc: 0
.9633Epoch 1/100
  1/163 [..............................] - ETA: 57s - loss: 0.1429 - acc:
0.9375
Epoch 00023: saving model to /content/data/model/weights.epoch_23.hdf5
163/163 [==============================] - 88s 542ms/step - loss: 0.1013 -
acc: 0.9632 - val_loss: 0.1429 - val_acc: 0.9375
Epoch 24/100
162/163 [============================>.] - ETA: 0s - loss: 0.1144 - acc: 0
.9608Epoch 1/100
  1/163 [..............................] - ETA: 56s - loss: 0.2555 - acc:
```

```
0.8750
Epoch 00024: saving model to /content/data/model/weights.epoch_24.hdf5
163/163 [==============================] - 88s 541ms/step - loss: 0.1139 -
acc: 0.9611 - val_loss: 0.2555 - val_acc: 0.8750
Epoch 25/100
162/163 [============================>.] - ETA: 0s - loss: 0.1158 - acc: 0
.9587Epoch 1/100
  1/163 [..............................] - ETA: 53s - loss: 0.3426 - acc:
0.8125
Epoch 00025: saving model to /content/data/model/weights.epoch_25.hdf5
163/163 [==============================] - 87s 536ms/step - loss: 0.1154 -
acc: 0.9588 - val_loss: 0.3426 - val_acc: 0.8125
Epoch 26/100
162/163 [============================>.] - ETA: 0s - loss: 0.1019 - acc: 0
.9657Epoch 1/100
  1/163 [..............................] - ETA: 57s - loss: 0.2778 - acc:
0.8750
Epoch 00026: saving model to /content/data/model/weights.epoch_26.hdf5
163/163 [==============================] - 89s 543ms/step - loss: 0.1030 -
acc: 0.9657 - val_loss: 0.2778 - val_acc: 0.8750
Epoch 27/100
162/163 [============================>.] - ETA: 0s - loss: 0.1105 - acc: 0
.9605Epoch 1/100
  1/163 [..............................] - ETA: 56s - loss: 0.3853 - acc:
0.8750
Epoch 00027: saving model to /content/data/model/weights.epoch_27.hdf5
163/163 [==============================] - 88s 540ms/step - loss: 0.1099 -
acc: 0.9607 - val_loss: 0.3853 - val_acc: 0.8750
Epoch 28/100
162/163 [============================>.] - ETA: 0s - loss: 0.1103 - acc: 0
.9610Epoch 1/100
  1/163 [..............................] - ETA: 53s - loss: 0.1571 - acc:
0.8750
Epoch 00028: saving model to /content/data/model/weights.epoch_28.hdf5
163/163 [==============================] - 87s 533ms/step - loss: 0.1098 -
acc: 0.9613 - val_loss: 0.1571 - val_acc: 0.8750
Epoch 29/100
162/163 [============================>.] - ETA: 0s - loss: 0.1073 - acc: 0
.9653Epoch 1/100
  1/163 [..............................] - ETA: 57s - loss: 0.2325 - acc:
0.8750
Epoch 00029: saving model to /content/data/model/weights.epoch_29.hdf5
163/163 [==============================] - 87s 531ms/step - loss: 0.1070 -
acc: 0.9655 - val_loss: 0.2325 - val_acc: 0.8750
Epoch 30/100
162/163 [============================>.] - ETA: 0s - loss: 0.0944 - acc: 0
.9670Epoch 1/100
  1/163 [..............................] - ETA: 55s - loss: 0.1494 - acc:
0.9375
Epoch 00030: saving model to /content/data/model/weights.epoch_30.hdf5
163/163 [==============================] - 87s 531ms/step - loss: 0.0947 -
acc: 0.9666 - val_loss: 0.1494 - val_acc: 0.9375
Epoch 31/100
162/163 [============================>.] - ETA: 0s - loss: 0.0893 - acc: 0
```

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.9678Epoch 1/100
  1/163 [..............................] - ETA: 56s - loss: 0.1171 - acc:
0.9375
Epoch 00031: saving model to /content/data/model/weights.epoch_31.hdf5
163/163 [==============================] - 88s 541ms/step - loss: 0.0893 -
acc: 0.9678 - val_loss: 0.1171 - val_acc: 0.9375
Epoch 32/100
162/163 [============================>.] - ETA: 0s - loss: 0.0974 - acc: 0
.9632Epoch 1/100
  1/163 [..............................] - ETA: 58s - loss: 0.1659 - acc:
0.8750
Epoch 00032: saving model to /content/data/model/weights.epoch_32.hdf5
163/163 [==============================] - 87s 533ms/step - loss: 0.0970 -
acc: 0.9634 - val_loss: 0.1659 - val_acc: 0.8750
Epoch 33/100
162/163 [============================>.] - ETA: 0s - loss: 0.0941 - acc: 0
.9668Epoch 1/100
  1/163 [..............................] - ETA: 57s - loss: 0.1246 - acc:
1.0000
Epoch 00033: saving model to /content/data/model/weights.epoch_33.hdf5
163/163 [==============================] - 87s 534ms/step - loss: 0.0942 -
acc: 0.9668 - val_loss: 0.1246 - val_acc: 1.0000
Epoch 34/100
162/163 [============================>.] - ETA: 0s - loss: 0.0914 - acc: 0
.9676Epoch 1/100
  1/163 [..............................] - ETA: 55s - loss: 0.3142 - acc:
0.8750
Epoch 00034: saving model to /content/data/model/weights.epoch_34.hdf5
163/163 [==============================] - 87s 533ms/step - loss: 0.0911 -
acc: 0.9678 - val_loss: 0.3142 - val_acc: 0.8750
Epoch 35/100
162/163 [============================>.] - ETA: 0s - loss: 0.0960 - acc: 0
.9653Epoch 1/100
  1/163 [..............................] - ETA: 55s - loss: 0.1748 - acc:
0.8750
Epoch 00035: saving model to /content/data/model/weights.epoch_35.hdf5
163/163 [==============================] - 86s 526ms/step - loss: 0.0964 -
acc: 0.9651 - val_loss: 0.1748 - val_acc: 0.8750
Epoch 36/100
162/163 [============================>.] - ETA: 0s - loss: 0.1011 - acc: 0
.9643Epoch 1/100
  1/163 [..............................] - ETA: 55s - loss: 0.2288 - acc:
0.8125
Epoch 00036: saving model to /content/data/model/weights.epoch_36.hdf5
163/163 [==============================] - 87s 536ms/step - loss: 0.1021 -
acc: 0.9641 - val_loss: 0.2288 - val_acc: 0.8125
Epoch 37/100
162/163 [============================>.] - ETA: 0s - loss: 0.0920 - acc: 0
.9699Epoch 1/100
  1/163 [..............................] - ETA: 55s - loss: 0.1580 - acc:
0.8750
Epoch 00037: saving model to /content/data/model/weights.epoch_37.hdf5
163/163 [==============================] - 87s 533ms/step - loss: 0.0934 -
acc: 0.9695 - val_loss: 0.1580 - val_acc: 0.8750
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Epoch 38/100
162/163 [============================>.] - ETA: 0s - loss: 0.0952 - acc: 0
.9674Epoch 1/100
  1/163 [..............................] - ETA: 55s - loss: 0.2501 - acc:
0.8750
Epoch 00038: saving model to /content/data/model/weights.epoch_38.hdf5
163/163 [==============================] - 87s 536ms/step - loss: 0.0961 -
acc: 0.9670 - val_loss: 0.2501 - val_acc: 0.8750
Epoch 39/100
162/163 [============================>.] - ETA: 0s - loss: 0.1001 - acc: 0
.9659Epoch 1/100
  1/163 [..............................] - ETA: 57s - loss: 0.1291 - acc:
0.9375
Epoch 00039: saving model to /content/data/model/weights.epoch_39.hdf5
163/163 [==============================] - 86s 531ms/step - loss: 0.1008 -
acc: 0.9657 - val_loss: 0.1291 - val_acc: 0.9375
Epoch 40/100
162/163 [============================>.] - ETA: 0s - loss: 0.1015 - acc: 0
.9637Epoch 1/100
  1/163 [..............................] - ETA: 55s - loss: 0.2680 - acc:
0.8750
Epoch 00040: saving model to /content/data/model/weights.epoch_40.hdf5
163/163 [==============================] - 88s 540ms/step - loss: 0.1012 -
acc: 0.9638 - val_loss: 0.2680 - val_acc: 0.8750
Epoch 41/100
162/163 [============================>.] - ETA: 0s - loss: 0.0939 - acc: 0
.9655Epoch 1/100
  1/163 [..............................] - ETA: 55s - loss: 0.1955 - acc:
0.8750
Epoch 00041: saving model to /content/data/model/weights.epoch_41.hdf5
163/163 [==============================] - 87s 534ms/step - loss: 0.0937 -
acc: 0.9657 - val_loss: 0.1955 - val_acc: 0.8750
Epoch 42/100
162/163 [============================>.] - ETA: 0s - loss: 0.0870 - acc: 0
.9693Epoch 1/100
  1/163 [..............................] - ETA: 57s - loss: 0.3026 - acc:
0.8125
Epoch 00042: saving model to /content/data/model/weights.epoch_42.hdf5
163/163 [==============================] - 87s 532ms/step - loss: 0.0874 -
acc: 0.9689 - val_loss: 0.3026 - val_acc: 0.8125
Epoch 43/100
162/163 [============================>.] - ETA: 0s - loss: 0.0911 - acc: 0
.9668Epoch 1/100
  1/163 [..............................] - ETA: 56s - loss: 0.1595 - acc:
0.8750
Epoch 00043: saving model to /content/data/model/weights.epoch_43.hdf5
163/163 [==============================] - 88s 538ms/step - loss: 0.0917 -
acc: 0.9664 - val_loss: 0.1595 - val_acc: 0.8750
Epoch 44/100
162/163 [============================>.] - ETA: 0s - loss: 0.0959 - acc: 0
.9674Epoch 1/100
  1/163 [..............................] - ETA: 54s - loss: 0.3788 - acc:
0.7500
Epoch 00044: saving model to /content/data/model/weights.epoch_44.hdf5
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163/163 [==============================] - 88s 542ms/step - loss: 0.0955 -
acc: 0.9676 - val_loss: 0.3788 - val_acc: 0.7500
Epoch 45/100
162/163 [============================>.] - ETA: 0s - loss: 0.0936 - acc: 0
.9676Epoch 1/100
  1/163 [..............................] - ETA: 57s - loss: 0.1382 - acc:
0.9375
Epoch 00045: saving model to /content/data/model/weights.epoch_45.hdf5
163/163 [==============================] - 87s 533ms/step - loss: 0.0938 -
acc: 0.9674 - val_loss: 0.1382 - val_acc: 0.9375
Epoch 46/100
162/163 [============================>.] - ETA: 0s - loss: 0.0894 - acc: 0
.9688Epoch 1/100
  1/163 [..............................] - ETA: 56s - loss: 0.1350 - acc:
0.9375
Epoch 00046: saving model to /content/data/model/weights.epoch_46.hdf5
163/163 [==============================] - 87s 537ms/step - loss: 0.0894 -
acc: 0.9688 - val_loss: 0.1350 - val_acc: 0.9375
Epoch 47/100
162/163 [============================>.] - ETA: 0s - loss: 0.1030 - acc: 0
.9630Epoch 1/100
  1/163 [..............................] - ETA: 56s - loss: 0.1182 - acc:
1.0000
Epoch 00047: saving model to /content/data/model/weights.epoch_47.hdf5
163/163 [==============================] - 87s 536ms/step - loss: 0.1034 -
acc: 0.9630 - val_loss: 0.1182 - val_acc: 1.0000
Epoch 48/100
162/163 [============================>.] - ETA: 0s - loss: 0.0949 - acc: 0
.9678Epoch 1/100
  1/163 [..............................] - ETA: 55s - loss: 0.1833 - acc:
0.8750
Epoch 00048: saving model to /content/data/model/weights.epoch_48.hdf5
163/163 [==============================] - 87s 536ms/step - loss: 0.0950 -
acc: 0.9678 - val_loss: 0.1833 - val_acc: 0.8750
Epoch 49/100
162/163 [============================>.] - ETA: 0s - loss: 0.0936 - acc: 0
.9659Epoch 1/100
  1/163 [..............................] - ETA: 55s - loss: 0.1593 - acc:
0.8750
Epoch 00049: saving model to /content/data/model/weights.epoch_49.hdf5
163/163 [==============================] - 87s 533ms/step - loss: 0.0931 -
acc: 0.9661 - val_loss: 0.1593 - val_acc: 0.8750
Epoch 50/100
162/163 [============================>.] - ETA: 0s - loss: 0.0848 - acc: 0
.9680Epoch 1/100
  1/163 [..............................] - ETA: 55s - loss: 0.1079 - acc:
0.9375
Epoch 00050: saving model to /content/data/model/weights.epoch_50.hdf5
163/163 [==============================] - 88s 541ms/step - loss: 0.0846 -
acc: 0.9682 - val_loss: 0.1079 - val_acc: 0.9375
Epoch 51/100
162/163 [============================>.] - ETA: 0s - loss: 0.0881 - acc: 0
.9697Epoch 1/100
  1/163 [..............................] - ETA: 53s - loss: 0.1095 - acc:
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1.0000
Epoch 00051: saving model to /content/data/model/weights.epoch_51.hdf5
163/163 [==============================] - 87s 534ms/step - loss: 0.0883 -
acc: 0.9695 - val_loss: 0.1095 - val_acc: 1.0000
Epoch 52/100
162/163 [============================>.] - ETA: 0s - loss: 0.0947 - acc: 0
.9688Epoch 1/100
  1/163 [..............................] - ETA: 53s - loss: 0.1149 - acc:
1.0000
Epoch 00052: saving model to /content/data/model/weights.epoch_52.hdf5
163/163 [==============================] - 87s 532ms/step - loss: 0.0944 -
acc: 0.9688 - val_loss: 0.1149 - val_acc: 1.0000
Epoch 53/100
162/163 [============================>.] - ETA: 0s - loss: 0.0895 - acc: 0
.9701Epoch 1/100
  1/163 [..............................] - ETA: 53s - loss: 0.2385 - acc:
0.8125
Epoch 00053: saving model to /content/data/model/weights.epoch_53.hdf5
163/163 [==============================] - 88s 538ms/step - loss: 0.0895 -
acc: 0.9701 - val_loss: 0.2385 - val_acc: 0.8125
Epoch 54/100
162/163 [============================>.] - ETA: 0s - loss: 0.0848 - acc: 0
.9703Epoch 1/100
  1/163 [..............................] - ETA: 54s - loss: 0.6372 - acc:
0.7500
Epoch 00054: saving model to /content/data/model/weights.epoch_54.hdf5
163/163 [==============================] - 86s 530ms/step - loss: 0.0870 -
acc: 0.9699 - val_loss: 0.6372 - val_acc: 0.7500
Epoch 55/100
162/163 [============================>.] - ETA: 0s - loss: 0.0879 - acc: 0
.9689Epoch 1/100
  1/163 [..............................] - ETA: 55s - loss: 0.1005 - acc:
1.0000
Epoch 00055: saving model to /content/data/model/weights.epoch_55.hdf5
163/163 [==============================] - 86s 528ms/step - loss: 0.0890 -
acc: 0.9686 - val_loss: 0.1005 - val_acc: 1.0000
Epoch 56/100
162/163 [============================>.] - ETA: 0s - loss: 0.0884 - acc: 0
.9688Epoch 1/100
  1/163 [..............................] - ETA: 55s - loss: 0.1344 - acc:
0.8750
Epoch 00056: saving model to /content/data/model/weights.epoch_56.hdf5
163/163 [==============================] - 86s 527ms/step - loss: 0.0884 -
acc: 0.9688 - val_loss: 0.1344 - val_acc: 0.8750
Epoch 57/100
162/163 [============================>.] - ETA: 0s - loss: 0.0875 - acc: 0
.9697Epoch 1/100
  1/163 [..............................] - ETA: 55s - loss: 0.2307 - acc:
0.8750
Epoch 00057: saving model to /content/data/model/weights.epoch_57.hdf5
163/163 [==============================] - 88s 539ms/step - loss: 0.0883 -
acc: 0.9693 - val_loss: 0.2307 - val_acc: 0.8750
Epoch 58/100
162/163 [============================>.] - ETA: 0s - loss: 0.0849 - acc: 0
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.9703Epoch 1/100
  1/163 [..............................] - ETA: 57s - loss: 0.1128 - acc:
1.0000
Epoch 00058: saving model to /content/data/model/weights.epoch_58.hdf5
163/163 [==============================] - 87s 532ms/step - loss: 0.0850 -
acc: 0.9703 - val_loss: 0.1128 - val_acc: 1.0000
Epoch 59/100
162/163 [============================>.] - ETA: 0s - loss: 0.0823 - acc: 0
.9701Epoch 1/100
  1/163 [..............................] - ETA: 56s - loss: 0.0822 - acc:
1.0000
Epoch 00059: saving model to /content/data/model/weights.epoch_59.hdf5
163/163 [==============================] - 87s 531ms/step - loss: 0.0820 -
acc: 0.9703 - val_loss: 0.0822 - val_acc: 1.0000
Epoch 60/100
162/163 [============================>.] - ETA: 0s - loss: 0.0902 - acc: 0
.9664Epoch 1/100
  1/163 [..............................] - ETA: 54s - loss: 0.2329 - acc:
0.8750
Epoch 00060: saving model to /content/data/model/weights.epoch_60.hdf5
163/163 [==============================] - 87s 532ms/step - loss: 0.0898 -
acc: 0.9666 - val_loss: 0.2329 - val_acc: 0.8750
Epoch 61/100
162/163 [============================>.] - ETA: 0s - loss: 0.0820 - acc: 0
.9711Epoch 1/100
  1/163 [..............................] - ETA: 55s - loss: 0.0746 - acc:
1.0000
Epoch 00061: saving model to /content/data/model/weights.epoch_61.hdf5
163/163 [==============================] - 88s 541ms/step - loss: 0.0826 -
acc: 0.9707 - val_loss: 0.0746 - val_acc: 1.0000
Epoch 62/100
162/163 [============================>.] - ETA: 0s - loss: 0.0909 - acc: 0
.9688Epoch 1/100
  1/163 [..............................] - ETA: 54s - loss: 0.1717 - acc:
0.8750
Epoch 00062: saving model to /content/data/model/weights.epoch_62.hdf5
163/163 [==============================] - 87s 537ms/step - loss: 0.0908 -
acc: 0.9688 - val_loss: 0.1717 - val_acc: 0.8750
Epoch 63/100
162/163 [============================>.] - ETA: 0s - loss: 0.0859 - acc: 0
.9697Epoch 1/100
  1/163 [..............................] - ETA: 54s - loss: 0.1260 - acc:
1.0000
Epoch 00063: saving model to /content/data/model/weights.epoch_63.hdf5
163/163 [==============================] - 87s 534ms/step - loss: 0.0862 -
acc: 0.9693 - val_loss: 0.1260 - val_acc: 1.0000
Epoch 64/100
162/163 [============================>.] - ETA: 0s - loss: 0.0954 - acc: 0
.9676Epoch 1/100
  1/163 [..............................] - ETA: 55s - loss: 0.0732 - acc:
1.0000
Epoch 00064: saving model to /content/data/model/weights.epoch_64.hdf5
163/163 [==============================] - 86s 529ms/step - loss: 0.0957 -
acc: 0.9676 - val_loss: 0.0732 - val_acc: 1.0000
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Epoch 65/100
162/163 [============================>.] - ETA: 0s - loss: 0.0829 - acc: 0
.9718Epoch 1/100
  1/163 [..............................] - ETA: 56s - loss: 0.1568 - acc:
0.8750
Epoch 00065: saving model to /content/data/model/weights.epoch_65.hdf5
163/163 [==============================] - 87s 534ms/step - loss: 0.0827 -
acc: 0.9720 - val_loss: 0.1568 - val_acc: 0.8750
Epoch 66/100
162/163 [============================>.] - ETA: 0s - loss: 0.0852 - acc: 0
.9701Epoch 1/100
  1/163 [..............................] - ETA: 57s - loss: 0.0780 - acc:
1.0000
Epoch 00066: saving model to /content/data/model/weights.epoch_66.hdf5
163/163 [==============================] - 88s 538ms/step - loss: 0.0852 -
acc: 0.9699 - val_loss: 0.0780 - val_acc: 1.0000
Epoch 67/100
162/163 [============================>.] - ETA: 0s - loss: 0.0906 - acc: 0
.9668Epoch 1/100
  1/163 [..............................] - ETA: 57s - loss: 0.0974 - acc:
0.9375
Epoch 00067: saving model to /content/data/model/weights.epoch_67.hdf5
163/163 [==============================] - 87s 532ms/step - loss: 0.0905 -
acc: 0.9668 - val_loss: 0.0974 - val_acc: 0.9375
Epoch 68/100
162/163 [============================>.] - ETA: 0s - loss: 0.0875 - acc: 0
.9662Epoch 1/100
  1/163 [..............................] - ETA: 56s - loss: 0.0688 - acc:
1.0000
Epoch 00068: saving model to /content/data/model/weights.epoch_68.hdf5
163/163 [==============================] - 88s 540ms/step - loss: 0.0873 -
acc: 0.9664 - val_loss: 0.0688 - val_acc: 1.0000
Epoch 69/100
162/163 [============================>.] - ETA: 0s - loss: 0.0850 - acc: 0
.9697Epoch 1/100
  1/163 [..............................] - ETA: 55s - loss: 0.2010 - acc:
0.8750
Epoch 00069: saving model to /content/data/model/weights.epoch_69.hdf5
163/163 [==============================] - 87s 532ms/step - loss: 0.0849 -
acc: 0.9697 - val_loss: 0.2010 - val_acc: 0.8750
Epoch 70/100
162/163 [============================>.] - ETA: 0s - loss: 0.0818 - acc: 0
.9699Epoch 1/100
  1/163 [..............................] - ETA: 56s - loss: 0.0961 - acc:
1.0000
Epoch 00070: saving model to /content/data/model/weights.epoch_70.hdf5
163/163 [==============================] - 88s 538ms/step - loss: 0.0819 -
acc: 0.9699 - val_loss: 0.0961 - val_acc: 1.0000
Epoch 71/100
162/163 [============================>.] - ETA: 0s - loss: 0.0798 - acc: 0
.9724Epoch 1/100
  1/163 [..............................] - ETA: 55s - loss: 0.1345 - acc:
0.8750
Epoch 00071: saving model to /content/data/model/weights.epoch_71.hdf5
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163/163 [==============================] - 87s 532ms/step - loss: 0.0795 -
acc: 0.9726 - val_loss: 0.1345 - val_acc: 0.8750
Epoch 72/100
162/163 [============================>.] - ETA: 0s - loss: 0.0745 - acc: 0
.9722Epoch 1/100
  1/163 [..............................] - ETA: 54s - loss: 0.0583 - acc:
1.0000
Epoch 00072: saving model to /content/data/model/weights.epoch_72.hdf5
163/163 [==============================] - 87s 536ms/step - loss: 0.0744 -
acc: 0.9722 - val_loss: 0.0583 - val_acc: 1.0000
Epoch 73/100
162/163 [============================>.] - ETA: 0s - loss: 0.0826 - acc: 0
.9715Epoch 1/100
  1/163 [..............................] - ETA: 53s - loss: 0.2599 - acc:
0.8125
Epoch 00073: saving model to /content/data/model/weights.epoch_73.hdf5
163/163 [==============================] - 86s 530ms/step - loss: 0.0825 -
acc: 0.9714 - val_loss: 0.2599 - val_acc: 0.8125
Epoch 74/100
162/163 [============================>.] - ETA: 0s - loss: 0.0801 - acc: 0
.9726Epoch 1/100
  1/163 [..............................] - ETA: 58s - loss: 0.0894 - acc:
1.0000
Epoch 00074: saving model to /content/data/model/weights.epoch_74.hdf5
163/163 [==============================] - 88s 538ms/step - loss: 0.0800 -
acc: 0.9726 - val_loss: 0.0894 - val_acc: 1.0000
Epoch 75/100
162/163 [============================>.] - ETA: 0s - loss: 0.0753 - acc: 0
.9751Epoch 1/100
  1/163 [..............................] - ETA: 53s - loss: 0.1020 - acc:
1.0000
Epoch 00075: saving model to /content/data/model/weights.epoch_75.hdf5
163/163 [==============================] - 88s 539ms/step - loss: 0.0752 -
acc: 0.9753 - val_loss: 0.1020 - val_acc: 1.0000
Epoch 76/100
162/163 [============================>.] - ETA: 0s - loss: 0.0833 - acc: 0
.9674Epoch 1/100
  1/163 [..............................] - ETA: 55s - loss: 0.1947 - acc:
0.8750
Epoch 00076: saving model to /content/data/model/weights.epoch_76.hdf5
163/163 [==============================] - 87s 537ms/step - loss: 0.0831 -
acc: 0.9674 - val_loss: 0.1947 - val_acc: 0.8750
Epoch 77/100
162/163 [============================>.] - ETA: 0s - loss: 0.0694 - acc: 0
.9761Epoch 1/100
  1/163 [..............................] - ETA: 54s - loss: 0.1262 - acc:
0.9375
Epoch 00077: saving model to /content/data/model/weights.epoch_77.hdf5
163/163 [==============================] - 87s 532ms/step - loss: 0.0701 -
acc: 0.9758 - val_loss: 0.1262 - val_acc: 0.9375
Epoch 78/100
162/163 [============================>.] - ETA: 0s - loss: 0.0814 - acc: 0
.9730Epoch 1/100
  1/163 [..............................] - ETA: 59s - loss: 0.0767 - acc:
```

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1.0000
Epoch 00078: saving model to /content/data/model/weights.epoch_78.hdf5
163/163 [==============================] - 87s 534ms/step - loss: 0.0812 -
acc: 0.9730 - val_loss: 0.0767 - val_acc: 1.0000
Epoch 79/100
162/163 [============================>.] - ETA: 0s - loss: 0.0819 - acc: 0
.9728Epoch 1/100
  1/163 [..............................] - ETA: 55s - loss: 0.0978 - acc:
1.0000
Epoch 00079: saving model to /content/data/model/weights.epoch_79.hdf5
163/163 [==============================] - 88s 539ms/step - loss: 0.0816 -
acc: 0.9730 - val_loss: 0.0978 - val_acc: 1.0000
Epoch 80/100
162/163 [============================>.] - ETA: 0s - loss: 0.0837 - acc: 0
.9718Epoch 1/100
  1/163 [..............................] - ETA: 54s - loss: 0.1157 - acc:
1.0000
Epoch 00080: saving model to /content/data/model/weights.epoch_80.hdf5
163/163 [==============================] - 86s 530ms/step - loss: 0.0836 -
acc: 0.9718 - val_loss: 0.1157 - val_acc: 1.0000
Epoch 81/100
162/163 [============================>.] - ETA: 0s - loss: 0.0783 - acc: 0
.9728Epoch 1/100
  1/163 [..............................] - ETA: 53s - loss: 0.3497 - acc:
0.8125
Epoch 00081: saving model to /content/data/model/weights.epoch_81.hdf5
163/163 [==============================] - 86s 529ms/step - loss: 0.0780 -
acc: 0.9730 - val_loss: 0.3497 - val_acc: 0.8125
Epoch 82/100
162/163 [============================>.] - ETA: 0s - loss: 0.0825 - acc: 0
.9688Epoch 1/100
  1/163 [..............................] - ETA: 57s - loss: 0.0968 - acc:
1.0000
Epoch 00082: saving model to /content/data/model/weights.epoch_82.hdf5
163/163 [==============================] - 86s 527ms/step - loss: 0.0822 -
acc: 0.9689 - val_loss: 0.0968 - val_acc: 1.0000
Epoch 83/100
162/163 [============================>.] - ETA: 0s - loss: 0.0865 - acc: 0
.9701Epoch 1/100
  1/163 [..............................] - ETA: 57s - loss: 0.1103 - acc:
0.9375
Epoch 00083: saving model to /content/data/model/weights.epoch_83.hdf5
163/163 [==============================] - 89s 547ms/step - loss: 0.0870 -
acc: 0.9701 - val_loss: 0.1103 - val_acc: 0.9375
Epoch 84/100
162/163 [============================>.] - ETA: 0s - loss: 0.0820 - acc: 0
.9730Epoch 1/100
  1/163 [..............................] - ETA: 54s - loss: 0.0963 - acc:
1.0000
Epoch 00084: saving model to /content/data/model/weights.epoch_84.hdf5
163/163 [==============================] - 88s 538ms/step - loss: 0.0817 -
acc: 0.9732 - val_loss: 0.0963 - val_acc: 1.0000
Epoch 85/100
162/163 [============================>.] - ETA: 0s - loss: 0.0771 - acc: 0
```

```
.9728Epoch 1/100
  1/163 [..............................] - ETA: 55s - loss: 0.0892 - acc: 
1.0000
Epoch 00085: saving model to /content/data/model/weights.epoch_85.hdf5
163/163 [==============================] - 89s 545ms/step - loss: 0.0768 - 
acc: 0.9728 - val_loss: 0.0892 - val_acc: 1.0000
Epoch 86/100
162/163 [============================>.] - ETA: 0s - loss: 0.0817 - acc: 0
.9716Epoch 1/100
  1/163 [..............................] - ETA: 56s - loss: 0.1064 - acc: 
0.9375
Epoch 00086: saving model to /content/data/model/weights.epoch_86.hdf5
163/163 [==============================] - 87s 534ms/step - loss: 0.0819 - 
acc: 0.9716 - val_loss: 0.1064 - val_acc: 0.9375
Epoch 87/100
162/163 [============================>.] - ETA: 0s - loss: 0.0824 - acc: 0
.9703Epoch 1/100
  1/163 [..............................] - ETA: 58s - loss: 0.1038 - acc: 
1.0000
Epoch 00087: saving model to /content/data/model/weights.epoch_87.hdf5
163/163 [==============================] - 88s 540ms/step - loss: 0.0824 - 
acc: 0.9703 - val_loss: 0.1038 - val_acc: 1.0000
Epoch 88/100
162/163 [============================>.] - ETA: 0s - loss: 0.0869 - acc: 0
.9716Epoch 1/100
  1/163 [..............................] - ETA: 56s - loss: 0.0846 - acc: 
0.9375
Epoch 00088: saving model to /content/data/model/weights.epoch_88.hdf5
163/163 [==============================] - 87s 534ms/step - loss: 0.0868 - 
acc: 0.9716 - val_loss: 0.0846 - val_acc: 0.9375
Epoch 89/100
162/163 [============================>.] - ETA: 0s - loss: 0.0782 - acc: 0
.9726Epoch 1/100
  1/163 [..............................] - ETA: 55s - loss: 0.1482 - acc: 
0.9375
Epoch 00089: saving model to /content/data/model/weights.epoch_89.hdf5
163/163 [==============================] - 87s 531ms/step - loss: 0.0790 - 
acc: 0.9722 - val_loss: 0.1482 - val_acc: 0.9375
Epoch 90/100
162/163 [============================>.] - ETA: 0s - loss: 0.0796 - acc: 0
.9713Epoch 1/100
  1/163 [..............................] - ETA: 54s - loss: 0.2667 - acc: 
0.8125
Epoch 00090: saving model to /content/data/model/weights.epoch_90.hdf5
163/163 [==============================] - 86s 530ms/step - loss: 0.0799 - 
acc: 0.9712 - val_loss: 0.2667 - val_acc: 0.8125
Epoch 91/100
162/163 [============================>.] - ETA: 0s - loss: 0.0806 - acc: 0
.9711Epoch 1/100
  1/163 [..............................] - ETA: 55s - loss: 0.1422 - acc: 
0.9375
Epoch 00091: saving model to /content/data/model/weights.epoch_91.hdf5
163/163 [==============================] - 86s 527ms/step - loss: 0.0807 - 
acc: 0.9711 - val_loss: 0.1422 - val_acc: 0.9375
```

```
Epoch 92/100
162/163 [============================>.] - ETA: 0s - loss: 0.0730 - acc: 0
.9743Epoch 1/100
  1/163 [..............................] - ETA: 56s - loss: 0.0867 - acc:
1.0000
Epoch 00092: saving model to /content/data/model/weights.epoch_92.hdf5
163/163 [==============================] - 88s 540ms/step - loss: 0.0734 -
acc: 0.9743 - val_loss: 0.0867 - val_acc: 1.0000
Epoch 93/100
162/163 [============================>.] - ETA: 0s - loss: 0.0810 - acc: 0
.9693Epoch 1/100
  1/163 [..............................] - ETA: 55s - loss: 0.0704 - acc:
0.9375
Epoch 00093: saving model to /content/data/model/weights.epoch_93.hdf5
163/163 [==============================] - 87s 533ms/step - loss: 0.0809 -
acc: 0.9693 - val_loss: 0.0704 - val_acc: 0.9375
Epoch 94/100
162/163 [============================>.] - ETA: 0s - loss: 0.0775 - acc: 0
.9713Epoch 1/100
  1/163 [..............................] - ETA: 55s - loss: 0.0916 - acc:
1.0000
Epoch 00094: saving model to /content/data/model/weights.epoch_94.hdf5
163/163 [==============================] - 86s 529ms/step - loss: 0.0776 -
acc: 0.9711 - val_loss: 0.0916 - val_acc: 1.0000
Epoch 95/100
162/163 [============================>.] - ETA: 0s - loss: 0.0790 - acc: 0
.9747Epoch 1/100
  1/163 [..............................] - ETA: 56s - loss: 0.0681 - acc:
1.0000
Epoch 00095: saving model to /content/data/model/weights.epoch_95.hdf5
163/163 [==============================] - 87s 535ms/step - loss: 0.0786 -
acc: 0.9749 - val_loss: 0.0681 - val_acc: 1.0000
Epoch 96/100
162/163 [============================>.] - ETA: 0s - loss: 0.0731 - acc: 0
.9724Epoch 1/100
  1/163 [..............................] - ETA: 58s - loss: 0.0682 - acc:
1.0000
Epoch 00096: saving model to /content/data/model/weights.epoch_96.hdf5
163/163 [==============================] - 88s 542ms/step - loss: 0.0731 -
acc: 0.9724 - val_loss: 0.0682 - val_acc: 1.0000
Epoch 97/100
162/163 [============================>.] - ETA: 0s - loss: 0.0777 - acc: 0
.9720Epoch 1/100
  1/163 [..............................] - ETA: 55s - loss: 0.0799 - acc:
1.0000
Epoch 00097: saving model to /content/data/model/weights.epoch_97.hdf5
163/163 [==============================] - 88s 539ms/step - loss: 0.0777 -
acc: 0.9718 - val_loss: 0.0799 - val_acc: 1.0000
Epoch 98/100
162/163 [============================>.] - ETA: 0s - loss: 0.0769 - acc: 0
.9743Epoch 1/100
  1/163 [..............................] - ETA: 54s - loss: 0.0810 - acc:
1.0000
Epoch 00098: saving model to /content/data/model/weights.epoch_98.hdf5
```

```
163/163 [==============================] - 86s 529ms/step - loss: 0.0767 - acc: 0.9745 - val_loss: 0.0810 - val_acc: 1.0000
Epoch 99/100
162/163 [============================>.] - ETA: 0s - loss: 0.0834 - acc: 0.9672Epoch 1/100
  1/163 [..............................] - ETA: 54s - loss: 0.1029 - acc: 1.0000
Epoch 00099: saving model to /content/data/model/weights.epoch_99.hdf5
163/163 [==============================] - 87s 531ms/step - loss: 0.0831 - acc: 0.9674 - val_loss: 0.1029 - val_acc: 1.0000
Epoch 100/100
162/163 [============================>.] - ETA: 0s - loss: 0.0826 - acc: 0.9709Epoch 1/100
  1/163 [..............................] - ETA: 56s - loss: 0.1546 - acc: 0.9375
Epoch 00100: saving model to /content/data/model/weights.epoch_100.hdf5
163/163 [==============================] - 87s 531ms/step - loss: 0.0838 - acc: 0.9705 - val_loss: 0.1546 - val_acc: 0.9375
```

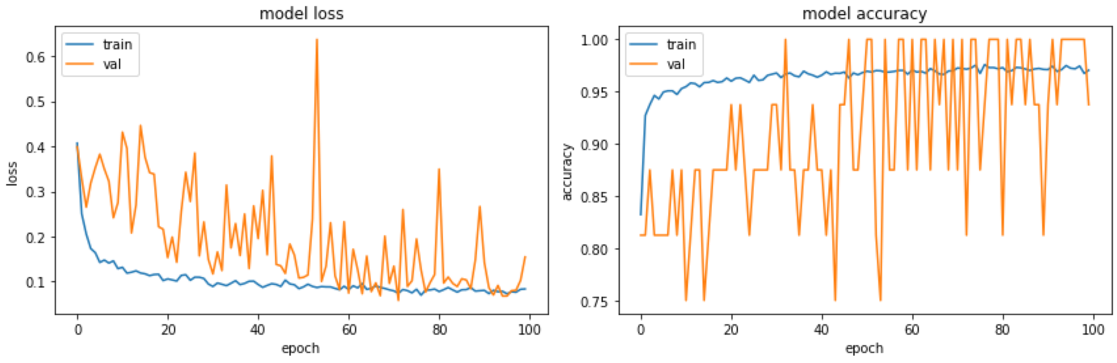
```
import matplotlib.pyplot as plt
def plot_learning_curves(history):
    plt.figure(figsize=(12,4))

    plt.subplot(1,2,1)
    plt.plot(history.history['loss'])
    plt.plot(history.history['val_loss'])
    plt.title('model loss')
    plt.ylabel('loss')
    plt.xlabel('epoch')
    plt.legend(['train', 'val'], loc='upper left')

    plt.subplot(1,2,2)
    plt.plot(history.history['acc'])
    plt.plot(history.history['val_acc'])
    plt.title('model accuracy')
    plt.ylabel('accuracy')
    plt.xlabel('epoch')
    plt.legend(['train', 'val'], loc='upper left')

    plt.tight_layout()

plot_learning_curves(history)
```



png

```
idx = np.argmin(history.history['val_loss'])
model.load_weights("/content/data/model/weights.epoch_{:02d}.hdf5".format(
idx + 1))

print("Loading the best model")
print("epoch: {}, val_loss: {}, val_acc: {}".format(idx + 1, history.histo
ry['val_loss'][idx], history.history['val_acc'][idx]))
```

```
Loading the best model
epoch: 72, val_loss: 0.05833631008863449, val_acc: 1.0
```

```
test_loss, test_acc = model.evaluate_generator(generator=test_generator, v
erbose=1)
```

```
20/20 [==============================] - 7s 330ms/step - loss: 0.2280 - ac
c: 0.9215
```

```
from sklearn.metrics import accuracy_score, confusion_matrix

test_generator.reset()
test_preds = model.predict_generator(test_generator, verbose=1)
test_preds = np.argmax(test_preds,axis=1)

acc = accuracy_score(test_generator.classes, test_preds)*100
cm = confusion_matrix(test_generator.classes, test_preds)
tn, fp, fn, tp = cm.ravel()

print('CONFUSION MATRIX ------------------')
print(cm)
# plot_confusion_matrix(cm, target_names=['NORMAL', 'PNEUMONIA'], normaliz
e=False)


print('\nTEST METRICS ----------------------')
precision = tp/(tp+fp)*100
recall = tp/(tp+fn)*100
print('Accuracy: {}%'.format(acc))
print('Precision: {}%'.format(precision))
print('Recall: {}%'.format(recall))
print('F1-score: {}'.format(2*precision*recall/(precision+recall)))
```

```
print('\nTRAIN METRIC ----------------------')
print('Train acc: {}%'.format(np.round((history.history['acc'][-1])*100, 1
4)))
```

```
20/20 [==============================] - 7s 355ms/step
CONFUSION MATRIX ------------------
[[203  31]
 [ 18 372]]

TEST METRICS ----------------------
Accuracy: 92.1474358974359%
Precision: 92.3076923076923%
Recall: 95.38461538461539%
F1-score: 93.82093316519547

TRAIN METRIC ----------------------
Train acc: 97.0475435256958%
```

9.8 Appendix H: VGG16 Model 2 Version 2.1.1.1.0

```
from __future__ import absolute_import, division, print_function, unicode_
literals
import tensorflow as tf

# Extract dataset
import os
import tarfile

import keras_preprocessing
from keras_preprocessing.image import ImageDataGenerator # Data preprocess
ing and augmentation

import sklearn
import numpy as np

print(tf.__version__)

1.15.0

# Make folder for chest xray data
!mkdir /content/data/

# Make directory to save weights
!mkdir /content/data/model

# Make directory to logs for Tensorboard
!mkdir /content/data/graph

# Download dataset
!wget --no-check-certificate \
    https://s3.eu-central-1.amazonaws.com/public.unit8.co/data/chest_xray.
tar.gz \
    -O /content/data/chest_xray.tar.gz

tar = tarfile.open("data/chest_xray.tar.gz")
tar.extractall(path='./data/')
os.remove('data/chest_xray.tar.gz')

mkdir: cannot create directory ‘/content/data/’: File exists
mkdir: cannot create directory ‘/content/data/model’: File exists
mkdir: cannot create directory ‘/content/data/graph’: File exists
--2019-10-29 04:11:13--  https://s3.eu-central-1.amazonaws.com/public.unit
8.co/data/chest_xray.tar.gz
Resolving s3.eu-central-1.amazonaws.com (s3.eu-central-1.amazonaws.com)...
52.219.73.175
Connecting to s3.eu-central-1.amazonaws.com (s3.eu-central-1.amazonaws.com
)|52.219.73.175|:443... connected.
HTTP request sent, awaiting response... 200 OK
Length: 1225393795 (1.1G) [application/x-gzip]
Saving to: ‘/content/data/chest_xray.tar.gz’

/content/data/chest 100%[===================>]   1.14G  26.2MB/s    in 46s
```

```
2019-10-29 04:11:59 (25.5 MB/s) - '/content/data/chest_xray.tar.gz' saved
[1225393795/1225393795]
```

Change log: > training_datagen –> ImageDataGenerator

trainable layer –> All except base

24 layers VGG16 model

Optimizer = RMSprop(learning_rate = 0.0001)

loss = categorical_crosscentropy

callback = [checkpoints]

epochs = 100

class weight balancing

```
TRAINING_DIR = "/content/data/chest_xray/train"
VALIDATION_DIR = "/content/data/chest_xray/val"
TEST_DIR = "/content/data/chest_xray/test"

training_datagen = ImageDataGenerator(
    preprocessing_function=tf.keras.applications.vgg16.preprocess_input,
    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,
    # vertical_flip=True
    fill_mode='nearest'
)

validation_datagen = ImageDataGenerator(
    rescale = 1./255
)

test_datagen = ImageDataGenerator(
    rescale = 1./255
)

# Create training data batch
# TODO: Try grayscaling the image to see what will happen
train_generator = training_datagen.flow_from_directory(
    TRAINING_DIR,
    target_size=(150,150),
    class_mode='categorical'
)

validation_generator = validation_datagen.flow_from_directory(
    VALIDATION_DIR,
    target_size=(150,150),
    class_mode='categorical'
```

```
)

test_generator = test_datagen.flow_from_directory(
    TEST_DIR,
    target_size=(150,150),
    class_mode='categorical',
    shuffle=False
)

train_shape = train_generator.image_shape

tf.keras.backend.clear_session() # Destroys the current TF graph and creat
es a new one.

base_model = tf.keras.applications.VGG16(weights='imagenet', include_top=F
alse, input_shape=train_shape)

x = base_model.output
x = tf.keras.layers.Flatten()(x)
x = tf.keras.layers.Dense(64, activation='relu')(x)
x = tf.keras.layers.Dropout(0.33)(x)
x = tf.keras.layers.BatchNormalization()(x)
x = tf.keras.layers.Dense(2, 'softmax')(x)

model = tf.keras.Model(inputs=base_model.input, outputs=x)

# for layer in model.layers[0:20]:
#     layer.trainable = False

for layer in base_model.layers:
  layer.trainable = False

optimizer = tf.keras.optimizers.RMSprop(learning_rate=0.0001) # Lower lear
ning rate by x10

model.compile(loss='categorical_crossentropy',
              optimizer=optimizer,
              metrics=['accuracy'])

# Callbacks stuff
# Function to save the weights of the model after each epoch
checkpoint = tf.keras.callbacks.ModelCheckpoint(
    '/content/data/model/weights.epoch_{epoch:02d}.hdf5',
    monitor='val_accuracy',
    save_best_only=False,
    save_weights_only=False,
    mode='auto',
    verbose=1
)

# Function to stop training early if there's no improvement
early_stopping_monitor = tf.keras.callbacks.EarlyStopping(patience = 3, mo
nitor = "val_loss", mode="auto", verbose = 1)
```

```
lr_reduce = tf.keras.callbacks.ReduceLROnPlateau(monitor='val_loss', facto
r=0.3, patience=2, verbose=1, mode='max')

classweight = sklearn.utils.class_weight.compute_class_weight('balanced',
np.unique(train_generator.labels), train_generator.labels)
print(classweight)

batch_size = 32
epochs = 100

# Training process
history = model.fit_generator(
    generator=train_generator,
    # steps_per_epoch=train_generator.samples//batch_size,
    epochs=epochs,
    # callbacks=[early_stopping_monitor],
    callbacks=[checkpoint],
    # shuffle=True,
    validation_data=validation_generator,
    # validation_steps= validation_generator//batch_size, #no because it's
gonna be 0... if leave alone its len(generator) which is equal to 1.
    class_weight=classweight,
    verbose = 1
)

# test_loss, test_acc = model.evaluate_generator(generator=test_generator,
verbose=1)
```

```
Found 5216 images belonging to 2 classes.
Found 16 images belonging to 2 classes.
Found 624 images belonging to 2 classes.
WARNING:tensorflow:From /usr/local/lib/python3.6/dist-packages/tensorflow_
core/python/ops/resource_variable_ops.py:1630: calling BaseResourceVariabl
e.__init__ (from tensorflow.python.ops.resource_variable_ops) with constra
int is deprecated and will be removed in a future version.
Instructions for updating:
If using Keras pass *_constraint arguments to layers.
Downloading data from https://github.com/fchollet/deep-learning-models/rel
eases/download/v0.1/vgg16_weights_tf_dim_ordering_tf_kernels_notop.h5
58892288/58889256 [==============================] - 1s 0us/step
[1.9448173  0.67303226]
Epoch 1/100
162/163 [============================>.] - ETA: 0s - loss: 0.3802 - acc: 0
.8480Epoch 1/100
  1/163 [..............................] - ETA: 4:49 - loss: 0.4098 - acc:
0.8125
Epoch 00001: saving model to /content/data/model/weights.epoch_01.hdf5
163/163 [==============================] - 101s 620ms/step - loss: 0.3808
- acc: 0.8478 - val_loss: 0.4098 - val_acc: 0.8125
Epoch 2/100
162/163 [============================>.] - ETA: 0s - loss: 0.2467 - acc: 0
.9267Epoch 1/100
  1/163 [..............................] - ETA: 58s - loss: 0.3625 - acc:
0.8125
```

```
Epoch 00002: saving model to /content/data/model/weights.epoch_02.hdf5
163/163 [==============================] - 97s 593ms/step - loss: 0.2467 -
acc: 0.9268 - val_loss: 0.3625 - val_acc: 0.8125
Epoch 3/100
162/163 [============================>.] - ETA: 0s - loss: 0.1974 - acc: 0
.9408Epoch 1/100
  1/163 [..............................] - ETA: 55s - loss: 0.3540 - acc:
0.8125
Epoch 00003: saving model to /content/data/model/weights.epoch_03.hdf5
163/163 [==============================] - 94s 575ms/step - loss: 0.1969 -
acc: 0.9410 - val_loss: 0.3540 - val_acc: 0.8125
Epoch 4/100
162/163 [============================>.] - ETA: 0s - loss: 0.1631 - acc: 0
.9518Epoch 1/100
  1/163 [..............................] - ETA: 56s - loss: 0.3638 - acc:
0.8125
Epoch 00004: saving model to /content/data/model/weights.epoch_04.hdf5
163/163 [==============================] - 85s 524ms/step - loss: 0.1632 -
acc: 0.9519 - val_loss: 0.3638 - val_acc: 0.8125
Epoch 5/100
162/163 [============================>.] - ETA: 0s - loss: 0.1548 - acc: 0
.9468Epoch 1/100
  1/163 [..............................] - ETA: 54s - loss: 0.4146 - acc:
0.8125
Epoch 00005: saving model to /content/data/model/weights.epoch_05.hdf5
163/163 [==============================] - 88s 538ms/step - loss: 0.1548 -
acc: 0.9467 - val_loss: 0.4146 - val_acc: 0.8125
Epoch 6/100
162/163 [============================>.] - ETA: 0s - loss: 0.1441 - acc: 0
.9545Epoch 1/100
  1/163 [..............................] - ETA: 59s - loss: 0.3516 - acc:
0.8125
Epoch 00006: saving model to /content/data/model/weights.epoch_06.hdf5
163/163 [==============================] - 90s 551ms/step - loss: 0.1443 -
acc: 0.9546 - val_loss: 0.3516 - val_acc: 0.8125
Epoch 7/100
162/163 [============================>.] - ETA: 0s - loss: 0.1440 - acc: 0
.9531Epoch 1/100
  1/163 [..............................] - ETA: 58s - loss: 0.2880 - acc:
0.8125
Epoch 00007: saving model to /content/data/model/weights.epoch_07.hdf5
163/163 [==============================] - 90s 553ms/step - loss: 0.1435 -
acc: 0.9534 - val_loss: 0.2880 - val_acc: 0.8125
Epoch 8/100
162/163 [============================>.] - ETA: 0s - loss: 0.1331 - acc: 0
.9545Epoch 1/100
  1/163 [..............................] - ETA: 57s - loss: 0.4213 - acc:
0.7500
Epoch 00008: saving model to /content/data/model/weights.epoch_08.hdf5
163/163 [==============================] - 90s 555ms/step - loss: 0.1340 -
acc: 0.9542 - val_loss: 0.4213 - val_acc: 0.7500
Epoch 9/100
162/163 [============================>.] - ETA: 0s - loss: 0.1265 - acc: 0
.9578Epoch 1/100
```

```
  1/163 [..............................] - ETA: 1:01 - loss: 0.2705 - acc: 
0.9375
Epoch 00009: saving model to /content/data/model/weights.epoch_09.hdf5
163/163 [==============================] - 90s 552ms/step - loss: 0.1267 - 
acc: 0.9576 - val_loss: 0.2705 - val_acc: 0.9375
Epoch 10/100
162/163 [============================>.] - ETA: 0s - loss: 0.1240 - acc: 0
.9560Epoch 1/100
  1/163 [..............................] - ETA: 55s - loss: 0.2467 - acc: 
0.8750
Epoch 00010: saving model to /content/data/model/weights.epoch_10.hdf5
163/163 [==============================] - 91s 560ms/step - loss: 0.1242 - 
acc: 0.9557 - val_loss: 0.2467 - val_acc: 0.8750
Epoch 11/100
162/163 [============================>.] - ETA: 0s - loss: 0.1154 - acc: 0
.9616Epoch 1/100
  1/163 [..............................] - ETA: 57s - loss: 0.2680 - acc: 
0.8750
Epoch 00011: saving model to /content/data/model/weights.epoch_11.hdf5
163/163 [==============================] - 91s 558ms/step - loss: 0.1150 - 
acc: 0.9618 - val_loss: 0.2680 - val_acc: 0.8750
Epoch 12/100
162/163 [============================>.] - ETA: 0s - loss: 0.1187 - acc: 0
.9593Epoch 1/100
  1/163 [..............................] - ETA: 56s - loss: 0.2426 - acc: 
0.8125
Epoch 00012: saving model to /content/data/model/weights.epoch_12.hdf5
163/163 [==============================] - 91s 557ms/step - loss: 0.1187 - 
acc: 0.9594 - val_loss: 0.2426 - val_acc: 0.8125
Epoch 13/100
162/163 [============================>.] - ETA: 0s - loss: 0.1176 - acc: 0
.9579Epoch 1/100
  1/163 [..............................] - ETA: 57s - loss: 0.3519 - acc: 
0.7500
Epoch 00013: saving model to /content/data/model/weights.epoch_13.hdf5
163/163 [==============================] - 91s 555ms/step - loss: 0.1179 - 
acc: 0.9580 - val_loss: 0.3519 - val_acc: 0.7500
Epoch 14/100
162/163 [============================>.] - ETA: 0s - loss: 0.1119 - acc: 0
.9589Epoch 1/100
  1/163 [..............................] - ETA: 1:02 - loss: 0.2501 - acc: 
0.8125
Epoch 00014: saving model to /content/data/model/weights.epoch_14.hdf5
163/163 [==============================] - 91s 557ms/step - loss: 0.1117 - 
acc: 0.9590 - val_loss: 0.2501 - val_acc: 0.8125
Epoch 15/100
162/163 [============================>.] - ETA: 0s - loss: 0.1129 - acc: 0
.9601Epoch 1/100
  1/163 [..............................] - ETA: 56s - loss: 0.2360 - acc: 
0.9375
Epoch 00015: saving model to /content/data/model/weights.epoch_15.hdf5
163/163 [==============================] - 92s 563ms/step - loss: 0.1141 - 
acc: 0.9595 - val_loss: 0.2360 - val_acc: 0.9375
Epoch 16/100
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162/163 [============================>.] - ETA: 0s - loss: 0.1100 - acc: 0
.9620Epoch 1/100
  1/163 [..............................] - ETA: 56s - loss: 0.2514 - acc:
0.8750
Epoch 00016: saving model to /content/data/model/weights.epoch_16.hdf5
163/163 [==============================] - 91s 559ms/step - loss: 0.1104 -
acc: 0.9618 - val_loss: 0.2514 - val_acc: 0.8750
Epoch 17/100
162/163 [============================>.] - ETA: 0s - loss: 0.1072 - acc: 0
.9589Epoch 1/100
  1/163 [..............................] - ETA: 55s - loss: 0.1747 - acc:
0.9375
Epoch 00017: saving model to /content/data/model/weights.epoch_17.hdf5
163/163 [==============================] - 92s 561ms/step - loss: 0.1073 -
acc: 0.9586 - val_loss: 0.1747 - val_acc: 0.9375
Epoch 18/100
162/163 [============================>.] - ETA: 0s - loss: 0.1099 - acc: 0
.9601Epoch 1/100
  1/163 [..............................] - ETA: 1:02 - loss: 0.2693 - acc:
0.8125
Epoch 00018: saving model to /content/data/model/weights.epoch_18.hdf5
163/163 [==============================] - 92s 563ms/step - loss: 0.1095 -
acc: 0.9603 - val_loss: 0.2693 - val_acc: 0.8125
Epoch 19/100
162/163 [============================>.] - ETA: 0s - loss: 0.1177 - acc: 0
.9597Epoch 1/100
  1/163 [..............................] - ETA: 55s - loss: 0.3865 - acc:
0.7500
Epoch 00019: saving model to /content/data/model/weights.epoch_19.hdf5
163/163 [==============================] - 91s 557ms/step - loss: 0.1181 -
acc: 0.9594 - val_loss: 0.3865 - val_acc: 0.7500
Epoch 20/100
162/163 [============================>.] - ETA: 0s - loss: 0.1034 - acc: 0
.9624Epoch 1/100
  1/163 [..............................] - ETA: 59s - loss: 0.3293 - acc:
0.8125
Epoch 00020: saving model to /content/data/model/weights.epoch_20.hdf5
163/163 [==============================] - 91s 560ms/step - loss: 0.1042 -
acc: 0.9622 - val_loss: 0.3293 - val_acc: 0.8125
Epoch 21/100
162/163 [============================>.] - ETA: 0s - loss: 0.1057 - acc: 0
.9612Epoch 1/100
  1/163 [..............................] - ETA: 58s - loss: 0.1473 - acc:
0.9375
Epoch 00021: saving model to /content/data/model/weights.epoch_21.hdf5
163/163 [==============================] - 91s 561ms/step - loss: 0.1054 -
acc: 0.9613 - val_loss: 0.1473 - val_acc: 0.9375
Epoch 22/100
162/163 [============================>.] - ETA: 0s - loss: 0.1071 - acc: 0
.9614Epoch 1/100
  1/163 [..............................] - ETA: 56s - loss: 0.1585 - acc:
0.9375
Epoch 00022: saving model to /content/data/model/weights.epoch_22.hdf5
163/163 [==============================] - 91s 558ms/step - loss: 0.1072 -
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acc: 0.9615 - val_loss: 0.1585 - val_acc: 0.9375
Epoch 23/100
162/163 [============================>.] - ETA: 0s - loss: 0.1027 - acc: 0
.9624Epoch 1/100
  1/163 [..............................] - ETA: 55s - loss: 0.2068 - acc:
0.9375
Epoch 00023: saving model to /content/data/model/weights.epoch_23.hdf5
163/163 [==============================] - 92s 562ms/step - loss: 0.1024 -
acc: 0.9626 - val_loss: 0.2068 - val_acc: 0.9375
Epoch 24/100
162/163 [============================>.] - ETA: 0s - loss: 0.1106 - acc: 0
.9624Epoch 1/100
  1/163 [..............................] - ETA: 1:01 - loss: 0.2637 - acc:
0.8125
Epoch 00024: saving model to /content/data/model/weights.epoch_24.hdf5
163/163 [==============================] - 91s 559ms/step - loss: 0.1104 -
acc: 0.9624 - val_loss: 0.2637 - val_acc: 0.8125
Epoch 25/100
162/163 [============================>.] - ETA: 0s - loss: 0.0990 - acc: 0
.9639Epoch 1/100
  1/163 [..............................] - ETA: 58s - loss: 0.2560 - acc:
0.8750
Epoch 00025: saving model to /content/data/model/weights.epoch_25.hdf5
163/163 [==============================] - 92s 563ms/step - loss: 0.0986 -
acc: 0.9641 - val_loss: 0.2560 - val_acc: 0.8750
Epoch 26/100
162/163 [============================>.] - ETA: 0s - loss: 0.1015 - acc: 0
.9666Epoch 1/100
  1/163 [..............................] - ETA: 58s - loss: 0.2135 - acc:
0.8125
Epoch 00026: saving model to /content/data/model/weights.epoch_26.hdf5
163/163 [==============================] - 92s 563ms/step - loss: 0.1013 -
acc: 0.9666 - val_loss: 0.2135 - val_acc: 0.8125
Epoch 27/100
162/163 [============================>.] - ETA: 0s - loss: 0.1028 - acc: 0
.9633Epoch 1/100
  1/163 [..............................] - ETA: 57s - loss: 0.2201 - acc:
0.8125
Epoch 00027: saving model to /content/data/model/weights.epoch_27.hdf5
163/163 [==============================] - 92s 563ms/step - loss: 0.1024 -
acc: 0.9636 - val_loss: 0.2201 - val_acc: 0.8125
Epoch 28/100
162/163 [============================>.] - ETA: 0s - loss: 0.0967 - acc: 0
.9664Epoch 1/100
  1/163 [..............................] - ETA: 57s - loss: 0.1996 - acc:
0.8750
Epoch 00028: saving model to /content/data/model/weights.epoch_28.hdf5
163/163 [==============================] - 92s 562ms/step - loss: 0.0974 -
acc: 0.9663 - val_loss: 0.1996 - val_acc: 0.8750
Epoch 29/100
162/163 [============================>.] - ETA: 0s - loss: 0.1130 - acc: 0
.9599Epoch 1/100
  1/163 [..............................] - ETA: 55s - loss: 0.3590 - acc:
0.8125
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Epoch 00029: saving model to /content/data/model/weights.epoch_29.hdf5
163/163 [==============================] - 91s 561ms/step - loss: 0.1125 -
acc: 0.9601 - val_loss: 0.3590 - val_acc: 0.8125
Epoch 30/100
162/163 [============================>.] - ETA: 0s - loss: 0.0935 - acc: 0
.9660Epoch 1/100
  1/163 [..............................] - ETA: 54s - loss: 0.2503 - acc:
0.8125
Epoch 00030: saving model to /content/data/model/weights.epoch_30.hdf5
163/163 [==============================] - 91s 560ms/step - loss: 0.0934 -
acc: 0.9661 - val_loss: 0.2503 - val_acc: 0.8125
Epoch 31/100
162/163 [============================>.] - ETA: 0s - loss: 0.1051 - acc: 0
.9630Epoch 1/100
  1/163 [..............................] - ETA: 55s - loss: 0.2337 - acc:
0.8125
Epoch 00031: saving model to /content/data/model/weights.epoch_31.hdf5
163/163 [==============================] - 89s 547ms/step - loss: 0.1047 -
acc: 0.9632 - val_loss: 0.2337 - val_acc: 0.8125
Epoch 32/100
162/163 [============================>.] - ETA: 0s - loss: 0.0945 - acc: 0
.9676Epoch 1/100
  1/163 [..............................] - ETA: 1:00 - loss: 0.4280 - acc:
0.7500
Epoch 00032: saving model to /content/data/model/weights.epoch_32.hdf5
163/163 [==============================] - 87s 536ms/step - loss: 0.0955 -
acc: 0.9670 - val_loss: 0.4280 - val_acc: 0.7500
Epoch 33/100
162/163 [============================>.] - ETA: 0s - loss: 0.0925 - acc: 0
.9662Epoch 1/100
  1/163 [..............................] - ETA: 55s - loss: 0.2131 - acc:
0.8750
Epoch 00033: saving model to /content/data/model/weights.epoch_33.hdf5
163/163 [==============================] - 89s 547ms/step - loss: 0.0923 -
acc: 0.9663 - val_loss: 0.2131 - val_acc: 0.8750
Epoch 34/100
162/163 [============================>.] - ETA: 0s - loss: 0.0964 - acc: 0
.9662Epoch 1/100
  1/163 [..............................] - ETA: 57s - loss: 0.1665 - acc:
0.8750
Epoch 00034: saving model to /content/data/model/weights.epoch_34.hdf5
163/163 [==============================] - 89s 547ms/step - loss: 0.0965 -
acc: 0.9663 - val_loss: 0.1665 - val_acc: 0.8750
Epoch 35/100
162/163 [============================>.] - ETA: 0s - loss: 0.1082 - acc: 0
.9632Epoch 1/100
  1/163 [..............................] - ETA: 57s - loss: 0.1668 - acc:
0.9375
Epoch 00035: saving model to /content/data/model/weights.epoch_35.hdf5
163/163 [==============================] - 90s 549ms/step - loss: 0.1078 -
acc: 0.9634 - val_loss: 0.1668 - val_acc: 0.9375
Epoch 36/100
162/163 [============================>.] - ETA: 0s - loss: 0.0995 - acc: 0
.9659Epoch 1/100
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  1/163 [..............................] - ETA: 57s - loss: 0.1578 - acc:
0.9375
Epoch 00036: saving model to /content/data/model/weights.epoch_36.hdf5
163/163 [==============================] - 90s 551ms/step - loss: 0.1000 -
acc: 0.9657 - val_loss: 0.1578 - val_acc: 0.9375
Epoch 37/100
162/163 [============================>.] - ETA: 0s - loss: 0.0978 - acc: 0
.9659Epoch 1/100
  1/163 [..............................] - ETA: 55s - loss: 0.1709 - acc:
0.8750
Epoch 00037: saving model to /content/data/model/weights.epoch_37.hdf5
163/163 [==============================] - 90s 550ms/step - loss: 0.0977 -
acc: 0.9661 - val_loss: 0.1709 - val_acc: 0.8750
Epoch 38/100
162/163 [============================>.] - ETA: 0s - loss: 0.0869 - acc: 0
.9711Epoch 1/100
  1/163 [..............................] - ETA: 55s - loss: 0.1146 - acc:
0.9375
Epoch 00038: saving model to /content/data/model/weights.epoch_38.hdf5
163/163 [==============================] - 89s 546ms/step - loss: 0.0868 -
acc: 0.9711 - val_loss: 0.1146 - val_acc: 0.9375
Epoch 39/100
162/163 [============================>.] - ETA: 0s - loss: 0.0909 - acc: 0
.9678Epoch 1/100
  1/163 [..............................] - ETA: 57s - loss: 0.1466 - acc:
0.9375
Epoch 00039: saving model to /content/data/model/weights.epoch_39.hdf5
163/163 [==============================] - 90s 553ms/step - loss: 0.0911 -
acc: 0.9676 - val_loss: 0.1466 - val_acc: 0.9375
Epoch 40/100
162/163 [============================>.] - ETA: 0s - loss: 0.0933 - acc: 0
.9682Epoch 1/100
  1/163 [..............................] - ETA: 56s - loss: 0.1306 - acc:
1.0000
Epoch 00040: saving model to /content/data/model/weights.epoch_40.hdf5
163/163 [==============================] - 89s 546ms/step - loss: 0.0937 -
acc: 0.9680 - val_loss: 0.1306 - val_acc: 1.0000
Epoch 41/100
162/163 [============================>.] - ETA: 0s - loss: 0.0853 - acc: 0
.9686Epoch 1/100
  1/163 [..............................] - ETA: 59s - loss: 0.1785 - acc:
0.9375
Epoch 00041: saving model to /content/data/model/weights.epoch_41.hdf5
163/163 [==============================] - 90s 554ms/step - loss: 0.0862 -
acc: 0.9684 - val_loss: 0.1785 - val_acc: 0.9375
Epoch 42/100
162/163 [============================>.] - ETA: 0s - loss: 0.0926 - acc: 0
.9680Epoch 1/100
  1/163 [..............................] - ETA: 56s - loss: 0.1822 - acc:
0.8750
Epoch 00042: saving model to /content/data/model/weights.epoch_42.hdf5
163/163 [==============================] - 90s 555ms/step - loss: 0.0923 -
acc: 0.9682 - val_loss: 0.1822 - val_acc: 0.8750
Epoch 43/100
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162/163 [============================>.] - ETA: 0s - loss: 0.0979 - acc: 0
.9662Epoch 1/100
  1/163 [..............................] - ETA: 57s - loss: 0.2030 - acc: 
0.8750
Epoch 00043: saving model to /content/data/model/weights.epoch_43.hdf5
163/163 [==============================] - 89s 549ms/step - loss: 0.0978 - 
acc: 0.9663 - val_loss: 0.2030 - val_acc: 0.8750
Epoch 44/100
162/163 [============================>.] - ETA: 0s - loss: 0.0952 - acc: 0
.9659Epoch 1/100
  1/163 [..............................] - ETA: 54s - loss: 0.1978 - acc: 
0.8750
Epoch 00044: saving model to /content/data/model/weights.epoch_44.hdf5
163/163 [==============================] - 88s 541ms/step - loss: 0.0948 - 
acc: 0.9661 - val_loss: 0.1978 - val_acc: 0.8750
Epoch 45/100
162/163 [============================>.] - ETA: 0s - loss: 0.0936 - acc: 0
.9678Epoch 1/100
  1/163 [..............................] - ETA: 58s - loss: 0.1818 - acc: 
0.8750
Epoch 00045: saving model to /content/data/model/weights.epoch_45.hdf5
163/163 [==============================] - 88s 542ms/step - loss: 0.0936 - 
acc: 0.9678 - val_loss: 0.1818 - val_acc: 0.8750
Epoch 46/100
162/163 [============================>.] - ETA: 0s - loss: 0.0861 - acc: 0
.9713Epoch 1/100
  1/163 [..............................] - ETA: 56s - loss: 0.1545 - acc: 
0.8750
Epoch 00046: saving model to /content/data/model/weights.epoch_46.hdf5
163/163 [==============================] - 90s 549ms/step - loss: 0.0857 - 
acc: 0.9714 - val_loss: 0.1545 - val_acc: 0.8750
Epoch 47/100
162/163 [============================>.] - ETA: 0s - loss: 0.0890 - acc: 0
.9709Epoch 1/100
  1/163 [..............................] - ETA: 54s - loss: 0.1602 - acc: 
0.9375
Epoch 00047: saving model to /content/data/model/weights.epoch_47.hdf5
163/163 [==============================] - 89s 548ms/step - loss: 0.0890 - 
acc: 0.9709 - val_loss: 0.1602 - val_acc: 0.9375
Epoch 48/100
162/163 [============================>.] - ETA: 0s - loss: 0.0929 - acc: 0
.9678Epoch 1/100
  1/163 [..............................] - ETA: 59s - loss: 0.0931 - acc: 
0.9375
Epoch 00048: saving model to /content/data/model/weights.epoch_48.hdf5
163/163 [==============================] - 90s 550ms/step - loss: 0.0927 - 
acc: 0.9678 - val_loss: 0.0931 - val_acc: 0.9375
Epoch 49/100
162/163 [============================>.] - ETA: 0s - loss: 0.0920 - acc: 0
.9711Epoch 1/100
  1/163 [..............................] - ETA: 55s - loss: 0.2514 - acc: 
0.8750
Epoch 00049: saving model to /content/data/model/weights.epoch_49.hdf5
163/163 [==============================] - 90s 553ms/step - loss: 0.0916 - 
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acc: 0.9712 - val_loss: 0.2514 - val_acc: 0.8750
Epoch 50/100
162/163 [============================>.] - ETA: 0s - loss: 0.0924 - acc: 0
.9693Epoch 1/100
  1/163 [..............................] - ETA: 55s - loss: 0.1498 - acc:
1.0000
Epoch 00050: saving model to /content/data/model/weights.epoch_50.hdf5
163/163 [==============================] - 90s 550ms/step - loss: 0.0933 -
acc: 0.9684 - val_loss: 0.1498 - val_acc: 1.0000
Epoch 51/100
162/163 [============================>.] - ETA: 0s - loss: 0.0896 - acc: 0
.9662Epoch 1/100
  1/163 [..............................] - ETA: 53s - loss: 0.1287 - acc:
0.9375
Epoch 00051: saving model to /content/data/model/weights.epoch_51.hdf5
163/163 [==============================] - 89s 548ms/step - loss: 0.0895 -
acc: 0.9664 - val_loss: 0.1287 - val_acc: 0.9375
Epoch 52/100
162/163 [============================>.] - ETA: 0s - loss: 0.0868 - acc: 0
.9682Epoch 1/100
  1/163 [..............................] - ETA: 58s - loss: 0.2034 - acc:
0.8750
Epoch 00052: saving model to /content/data/model/weights.epoch_52.hdf5
163/163 [==============================] - 91s 557ms/step - loss: 0.0875 -
acc: 0.9678 - val_loss: 0.2034 - val_acc: 0.8750
Epoch 53/100
162/163 [============================>.] - ETA: 0s - loss: 0.0898 - acc: 0
.9680Epoch 1/100
  1/163 [..............................] - ETA: 54s - loss: 0.0875 - acc:
1.0000
Epoch 00053: saving model to /content/data/model/weights.epoch_53.hdf5
163/163 [==============================] - 91s 555ms/step - loss: 0.0896 -
acc: 0.9680 - val_loss: 0.0875 - val_acc: 1.0000
Epoch 54/100
162/163 [============================>.] - ETA: 0s - loss: 0.0914 - acc: 0
.9697Epoch 1/100
  1/163 [..............................] - ETA: 58s - loss: 0.2708 - acc:
0.8750
Epoch 00054: saving model to /content/data/model/weights.epoch_54.hdf5
163/163 [==============================] - 90s 550ms/step - loss: 0.0919 -
acc: 0.9695 - val_loss: 0.2708 - val_acc: 0.8750
Epoch 55/100
162/163 [============================>.] - ETA: 0s - loss: 0.0914 - acc: 0
.9680Epoch 1/100
  1/163 [..............................] - ETA: 58s - loss: 0.1194 - acc:
1.0000
Epoch 00055: saving model to /content/data/model/weights.epoch_55.hdf5
163/163 [==============================] - 89s 548ms/step - loss: 0.0910 -
acc: 0.9682 - val_loss: 0.1194 - val_acc: 1.0000
Epoch 56/100
162/163 [============================>.] - ETA: 0s - loss: 0.0851 - acc: 0
.9699Epoch 1/100
  1/163 [..............................] - ETA: 55s - loss: 0.1983 - acc:
0.8750
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Epoch 00056: saving model to /content/data/model/weights.epoch_56.hdf5
163/163 [==============================] - 90s 550ms/step - loss: 0.0850 -
acc: 0.9699 - val_loss: 0.1983 - val_acc: 0.8750
Epoch 57/100
162/163 [============================>.] - ETA: 0s - loss: 0.0849 - acc: 0
.9732Epoch 1/100
  1/163 [..............................] - ETA: 55s - loss: 0.1570 - acc:
0.8750
Epoch 00057: saving model to /content/data/model/weights.epoch_57.hdf5
163/163 [==============================] - 89s 549ms/step - loss: 0.0845 -
acc: 0.9734 - val_loss: 0.1570 - val_acc: 0.8750
Epoch 58/100
162/163 [============================>.] - ETA: 0s - loss: 0.0887 - acc: 0
.9688Epoch 1/100
  1/163 [..............................] - ETA: 58s - loss: 0.1099 - acc:
1.0000
Epoch 00058: saving model to /content/data/model/weights.epoch_58.hdf5
163/163 [==============================] - 89s 546ms/step - loss: 0.0883 -
acc: 0.9689 - val_loss: 0.1099 - val_acc: 1.0000
Epoch 59/100
162/163 [============================>.] - ETA: 0s - loss: 0.0835 - acc: 0
.9705Epoch 1/100
  1/163 [..............................] - ETA: 55s - loss: 0.1104 - acc:
1.0000
Epoch 00059: saving model to /content/data/model/weights.epoch_59.hdf5
163/163 [==============================] - 89s 546ms/step - loss: 0.0837 -
acc: 0.9703 - val_loss: 0.1104 - val_acc: 1.0000
Epoch 60/100
162/163 [============================>.] - ETA: 0s - loss: 0.0908 - acc: 0
.9662Epoch 1/100
  1/163 [..............................] - ETA: 55s - loss: 0.1089 - acc:
1.0000
Epoch 00060: saving model to /content/data/model/weights.epoch_60.hdf5
163/163 [==============================] - 89s 548ms/step - loss: 0.0907 -
acc: 0.9663 - val_loss: 0.1089 - val_acc: 1.0000
Epoch 61/100
162/163 [============================>.] - ETA: 0s - loss: 0.0908 - acc: 0
.9689Epoch 1/100
  1/163 [..............................] - ETA: 58s - loss: 0.1040 - acc:
1.0000
Epoch 00061: saving model to /content/data/model/weights.epoch_61.hdf5
163/163 [==============================] - 90s 549ms/step - loss: 0.0907 -
acc: 0.9689 - val_loss: 0.1040 - val_acc: 1.0000
Epoch 62/100
162/163 [============================>.] - ETA: 0s - loss: 0.0866 - acc: 0
.9686Epoch 1/100
  1/163 [..............................] - ETA: 56s - loss: 0.0850 - acc:
0.9375
Epoch 00062: saving model to /content/data/model/weights.epoch_62.hdf5
163/163 [==============================] - 90s 550ms/step - loss: 0.0872 -
acc: 0.9682 - val_loss: 0.0850 - val_acc: 0.9375
Epoch 63/100
162/163 [============================>.] - ETA: 0s - loss: 0.0908 - acc: 0
.9680Epoch 1/100
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  1/163 [..............................] - ETA: 55s - loss: 0.0773 - acc:
1.0000
Epoch 00063: saving model to /content/data/model/weights.epoch_63.hdf5
163/163 [==============================] - 90s 554ms/step - loss: 0.0912 -
acc: 0.9680 - val_loss: 0.0773 - val_acc: 1.0000
Epoch 64/100
162/163 [============================>.] - ETA: 0s - loss: 0.0943 - acc: 0
.9680Epoch 1/100
  1/163 [..............................] - ETA: 58s - loss: 0.0843 - acc:
1.0000
Epoch 00064: saving model to /content/data/model/weights.epoch_64.hdf5
163/163 [==============================] - 90s 550ms/step - loss: 0.0939 -
acc: 0.9682 - val_loss: 0.0843 - val_acc: 1.0000
Epoch 65/100
162/163 [============================>.] - ETA: 0s - loss: 0.0948 - acc: 0
.9666Epoch 1/100
  1/163 [..............................] - ETA: 58s - loss: 0.1199 - acc:
1.0000
Epoch 00065: saving model to /content/data/model/weights.epoch_65.hdf5
163/163 [==============================] - 90s 551ms/step - loss: 0.0945 -
acc: 0.9668 - val_loss: 0.1199 - val_acc: 1.0000
Epoch 66/100
162/163 [============================>.] - ETA: 0s - loss: 0.0889 - acc: 0
.9664Epoch 1/100
  1/163 [..............................] - ETA: 58s - loss: 0.2478 - acc:
0.8750
Epoch 00066: saving model to /content/data/model/weights.epoch_66.hdf5
163/163 [==============================] - 91s 555ms/step - loss: 0.0914 -
acc: 0.9661 - val_loss: 0.2478 - val_acc: 0.8750
Epoch 67/100
162/163 [============================>.] - ETA: 0s - loss: 0.0983 - acc: 0
.9664Epoch 1/100
  1/163 [..............................] - ETA: 56s - loss: 0.1133 - acc:
0.9375
Epoch 00067: saving model to /content/data/model/weights.epoch_67.hdf5
163/163 [==============================] - 90s 552ms/step - loss: 0.0983 -
acc: 0.9664 - val_loss: 0.1133 - val_acc: 0.9375
Epoch 68/100
162/163 [============================>.] - ETA: 0s - loss: 0.0903 - acc: 0
.9688Epoch 1/100
  1/163 [..............................] - ETA: 56s - loss: 0.1708 - acc:
0.8750
Epoch 00068: saving model to /content/data/model/weights.epoch_68.hdf5
163/163 [==============================] - 90s 553ms/step - loss: 0.0905 -
acc: 0.9684 - val_loss: 0.1708 - val_acc: 0.8750
Epoch 69/100
162/163 [============================>.] - ETA: 0s - loss: 0.0911 - acc: 0
.9649Epoch 1/100
  1/163 [..............................] - ETA: 55s - loss: 0.0929 - acc:
1.0000
Epoch 00069: saving model to /content/data/model/weights.epoch_69.hdf5
163/163 [==============================] - 90s 549ms/step - loss: 0.0908 -
acc: 0.9649 - val_loss: 0.0929 - val_acc: 1.0000
Epoch 70/100
```

```
162/163 [============================>.] - ETA: 0s - loss: 0.0886 - acc: 0
.9674Epoch 1/100
  1/163 [..............................] - ETA: 57s - loss: 0.2361 - acc:
0.8750
Epoch 00070: saving model to /content/data/model/weights.epoch_70.hdf5
163/163 [==============================] - 90s 549ms/step - loss: 0.0888 -
acc: 0.9674 - val_loss: 0.2361 - val_acc: 0.8750
Epoch 71/100
162/163 [============================>.] - ETA: 0s - loss: 0.0844 - acc: 0
.9713Epoch 1/100
  1/163 [..............................] - ETA: 56s - loss: 0.1138 - acc:
1.0000
Epoch 00071: saving model to /content/data/model/weights.epoch_71.hdf5
163/163 [==============================] - 89s 546ms/step - loss: 0.0845 -
acc: 0.9712 - val_loss: 0.1138 - val_acc: 1.0000
Epoch 72/100
162/163 [============================>.] - ETA: 0s - loss: 0.0767 - acc: 0
.9730Epoch 1/100
  1/163 [..............................] - ETA: 56s - loss: 0.2393 - acc:
0.9375
Epoch 00072: saving model to /content/data/model/weights.epoch_72.hdf5
163/163 [==============================] - 89s 545ms/step - loss: 0.0781 -
acc: 0.9726 - val_loss: 0.2393 - val_acc: 0.9375
Epoch 73/100
162/163 [============================>.] - ETA: 0s - loss: 0.0840 - acc: 0
.9695Epoch 1/100
  1/163 [..............................] - ETA: 58s - loss: 0.0807 - acc:
0.9375
Epoch 00073: saving model to /content/data/model/weights.epoch_73.hdf5
163/163 [==============================] - 90s 551ms/step - loss: 0.0838 -
acc: 0.9695 - val_loss: 0.0807 - val_acc: 0.9375
Epoch 74/100
162/163 [============================>.] - ETA: 0s - loss: 0.0964 - acc: 0
.9660Epoch 1/100
  1/163 [..............................] - ETA: 56s - loss: 0.1297 - acc:
0.9375
Epoch 00074: saving model to /content/data/model/weights.epoch_74.hdf5
163/163 [==============================] - 89s 549ms/step - loss: 0.0959 -
acc: 0.9663 - val_loss: 0.1297 - val_acc: 0.9375
Epoch 75/100
162/163 [============================>.] - ETA: 0s - loss: 0.0766 - acc: 0
.9730Epoch 1/100
  1/163 [..............................] - ETA: 56s - loss: 0.1688 - acc:
0.9375
Epoch 00075: saving model to /content/data/model/weights.epoch_75.hdf5
163/163 [==============================] - 89s 548ms/step - loss: 0.0765 -
acc: 0.9730 - val_loss: 0.1688 - val_acc: 0.9375
Epoch 76/100
162/163 [============================>.] - ETA: 0s - loss: 0.0785 - acc: 0
.9707Epoch 1/100
  1/163 [..............................] - ETA: 57s - loss: 0.2829 - acc:
0.7500
Epoch 00076: saving model to /content/data/model/weights.epoch_76.hdf5
163/163 [==============================] - 90s 550ms/step - loss: 0.0784 -
```

```
acc: 0.9707 - val_loss: 0.2829 - val_acc: 0.7500
Epoch 77/100
162/163 [============================>.] - ETA: 0s - loss: 0.0839 - acc: 0
.9682Epoch 1/100
  1/163 [..............................] - ETA: 56s - loss: 0.0655 - acc:
1.0000
Epoch 00077: saving model to /content/data/model/weights.epoch_77.hdf5
163/163 [==============================] - 91s 556ms/step - loss: 0.0836 -
acc: 0.9684 - val_loss: 0.0655 - val_acc: 1.0000
Epoch 78/100
162/163 [============================>.] - ETA: 0s - loss: 0.0780 - acc: 0
.9732Epoch 1/100
  1/163 [..............................] - ETA: 57s - loss: 0.0590 - acc:
1.0000
Epoch 00078: saving model to /content/data/model/weights.epoch_78.hdf5
163/163 [==============================] - 90s 553ms/step - loss: 0.0777 -
acc: 0.9734 - val_loss: 0.0590 - val_acc: 1.0000
Epoch 79/100
162/163 [============================>.] - ETA: 0s - loss: 0.0826 - acc: 0
.9718Epoch 1/100
  1/163 [..............................] - ETA: 56s - loss: 0.1054 - acc:
0.9375
Epoch 00079: saving model to /content/data/model/weights.epoch_79.hdf5
163/163 [==============================] - 90s 553ms/step - loss: 0.0823 -
acc: 0.9720 - val_loss: 0.1054 - val_acc: 0.9375
Epoch 80/100
162/163 [============================>.] - ETA: 0s - loss: 0.0765 - acc: 0
.9740Epoch 1/100
  1/163 [..............................] - ETA: 58s - loss: 0.1753 - acc:
0.8750
Epoch 00080: saving model to /content/data/model/weights.epoch_80.hdf5
163/163 [==============================] - 90s 553ms/step - loss: 0.0763 -
acc: 0.9741 - val_loss: 0.1753 - val_acc: 0.8750
Epoch 81/100
162/163 [============================>.] - ETA: 0s - loss: 0.0812 - acc: 0
.9699Epoch 1/100
  1/163 [..............................] - ETA: 55s - loss: 0.2651 - acc:
0.8750
Epoch 00081: saving model to /content/data/model/weights.epoch_81.hdf5
163/163 [==============================] - 90s 551ms/step - loss: 0.0809 -
acc: 0.9701 - val_loss: 0.2651 - val_acc: 0.8750
Epoch 82/100
162/163 [============================>.] - ETA: 0s - loss: 0.0869 - acc: 0
.9705Epoch 1/100
  1/163 [..............................] - ETA: 58s - loss: 0.3787 - acc:
0.7500
Epoch 00082: saving model to /content/data/model/weights.epoch_82.hdf5
163/163 [==============================] - 89s 545ms/step - loss: 0.0865 -
acc: 0.9707 - val_loss: 0.3787 - val_acc: 0.7500
Epoch 83/100
162/163 [============================>.] - ETA: 0s - loss: 0.0887 - acc: 0
.9691Epoch 1/100
  1/163 [..............................] - ETA: 58s - loss: 0.2015 - acc:
0.8750
```

```
Epoch 00083: saving model to /content/data/model/weights.epoch_83.hdf5
163/163 [==============================] - 89s 547ms/step - loss: 0.0885 -
acc: 0.9691 - val_loss: 0.2015 - val_acc: 0.8750
Epoch 84/100
162/163 [============================>.] - ETA: 0s - loss: 0.0846 - acc: 0
.9701Epoch 1/100
  1/163 [..............................] - ETA: 59s - loss: 0.1080 - acc:
1.0000
Epoch 00084: saving model to /content/data/model/weights.epoch_84.hdf5
163/163 [==============================] - 89s 548ms/step - loss: 0.0842 -
acc: 0.9703 - val_loss: 0.1080 - val_acc: 1.0000
Epoch 85/100
162/163 [============================>.] - ETA: 0s - loss: 0.0929 - acc: 0
.9684Epoch 1/100
  1/163 [..............................] - ETA: 57s - loss: 0.0726 - acc:
1.0000
Epoch 00085: saving model to /content/data/model/weights.epoch_85.hdf5
163/163 [==============================] - 89s 548ms/step - loss: 0.0924 -
acc: 0.9686 - val_loss: 0.0726 - val_acc: 1.0000
Epoch 86/100
162/163 [============================>.] - ETA: 0s - loss: 0.0847 - acc: 0
.9701Epoch 1/100
  1/163 [..............................] - ETA: 56s - loss: 0.1016 - acc:
1.0000
Epoch 00086: saving model to /content/data/model/weights.epoch_86.hdf5
163/163 [==============================] - 89s 547ms/step - loss: 0.0845 -
acc: 0.9701 - val_loss: 0.1016 - val_acc: 1.0000
Epoch 87/100
162/163 [============================>.] - ETA: 0s - loss: 0.0818 - acc: 0
.9722Epoch 1/100
  1/163 [..............................] - ETA: 56s - loss: 0.0875 - acc:
0.9375
Epoch 00087: saving model to /content/data/model/weights.epoch_87.hdf5
163/163 [==============================] - 89s 548ms/step - loss: 0.0822 -
acc: 0.9718 - val_loss: 0.0875 - val_acc: 0.9375
Epoch 88/100
162/163 [============================>.] - ETA: 0s - loss: 0.0775 - acc: 0
.9751Epoch 1/100
  1/163 [..............................] - ETA: 55s - loss: 0.1044 - acc:
1.0000
Epoch 00088: saving model to /content/data/model/weights.epoch_88.hdf5
163/163 [==============================] - 90s 550ms/step - loss: 0.0777 -
acc: 0.9749 - val_loss: 0.1044 - val_acc: 1.0000
Epoch 89/100
162/163 [============================>.] - ETA: 0s - loss: 0.0717 - acc: 0
.9743Epoch 1/100
  1/163 [..............................] - ETA: 57s - loss: 0.1166 - acc:
1.0000
Epoch 00089: saving model to /content/data/model/weights.epoch_89.hdf5
163/163 [==============================] - 89s 546ms/step - loss: 0.0714 -
acc: 0.9745 - val_loss: 0.1166 - val_acc: 1.0000
Epoch 90/100
162/163 [============================>.] - ETA: 0s - loss: 0.0875 - acc: 0
.9684Epoch 1/100
```

```
  1/163 [..............................] - ETA: 55s - loss: 0.1030 - acc: 
0.9375
Epoch 00090: saving model to /content/data/model/weights.epoch_90.hdf5
163/163 [==============================] - 89s 544ms/step - loss: 0.0871 - 
acc: 0.9686 - val_loss: 0.1030 - val_acc: 0.9375
Epoch 91/100
162/163 [============================>.] - ETA: 0s - loss: 0.0774 - acc: 0
.9718Epoch 1/100
  1/163 [..............................] - ETA: 55s - loss: 0.1324 - acc: 
0.8750
Epoch 00091: saving model to /content/data/model/weights.epoch_91.hdf5
163/163 [==============================] - 90s 550ms/step - loss: 0.0770 - 
acc: 0.9720 - val_loss: 0.1324 - val_acc: 0.8750
Epoch 92/100
162/163 [============================>.] - ETA: 0s - loss: 0.0756 - acc: 0
.9736Epoch 1/100
  1/163 [..............................] - ETA: 55s - loss: 0.0777 - acc: 
1.0000
Epoch 00092: saving model to /content/data/model/weights.epoch_92.hdf5
163/163 [==============================] - 90s 551ms/step - loss: 0.0753 - 
acc: 0.9737 - val_loss: 0.0777 - val_acc: 1.0000
Epoch 93/100
162/163 [============================>.] - ETA: 0s - loss: 0.0778 - acc: 0
.9707Epoch 1/100
  1/163 [..............................] - ETA: 57s - loss: 0.0962 - acc: 
0.9375
Epoch 00093: saving model to /content/data/model/weights.epoch_93.hdf5
163/163 [==============================] - 89s 548ms/step - loss: 0.0783 - 
acc: 0.9701 - val_loss: 0.0962 - val_acc: 0.9375
Epoch 94/100
162/163 [============================>.] - ETA: 0s - loss: 0.0835 - acc: 0
.9715Epoch 1/100
  1/163 [..............................] - ETA: 56s - loss: 0.2383 - acc: 
0.8750
Epoch 00094: saving model to /content/data/model/weights.epoch_94.hdf5
163/163 [==============================] - 90s 550ms/step - loss: 0.0831 - 
acc: 0.9716 - val_loss: 0.2383 - val_acc: 0.8750
Epoch 95/100
162/163 [============================>.] - ETA: 0s - loss: 0.0758 - acc: 0
.9757Epoch 1/100
  1/163 [..............................] - ETA: 58s - loss: 0.0441 - acc: 
1.0000
Epoch 00095: saving model to /content/data/model/weights.epoch_95.hdf5
163/163 [==============================] - 90s 552ms/step - loss: 0.0769 - 
acc: 0.9757 - val_loss: 0.0441 - val_acc: 1.0000
Epoch 96/100
162/163 [============================>.] - ETA: 0s - loss: 0.0728 - acc: 0
.9734Epoch 1/100
  1/163 [..............................] - ETA: 58s - loss: 0.1091 - acc: 
1.0000
Epoch 00096: saving model to /content/data/model/weights.epoch_96.hdf5
163/163 [==============================] - 89s 549ms/step - loss: 0.0725 - 
acc: 0.9735 - val_loss: 0.1091 - val_acc: 1.0000
Epoch 97/100
```

```
162/163 [============================>.] - ETA: 0s - loss: 0.0753 - acc: 0
.9745Epoch 1/100
  1/163 [..............................] - ETA: 57s - loss: 0.1151 - acc:
0.9375
Epoch 00097: saving model to /content/data/model/weights.epoch_97.hdf5
163/163 [==============================] - 90s 553ms/step - loss: 0.0753 -
acc: 0.9745 - val_loss: 0.1151 - val_acc: 0.9375
Epoch 98/100
162/163 [============================>.] - ETA: 0s - loss: 0.0771 - acc: 0
.9716Epoch 1/100
  1/163 [..............................] - ETA: 58s - loss: 0.0734 - acc:
0.9375
Epoch 00098: saving model to /content/data/model/weights.epoch_98.hdf5
163/163 [==============================] - 90s 555ms/step - loss: 0.0771 -
acc: 0.9716 - val_loss: 0.0734 - val_acc: 0.9375
Epoch 99/100
162/163 [============================>.] - ETA: 0s - loss: 0.0748 - acc: 0
.9745Epoch 1/100
  1/163 [..............................] - ETA: 55s - loss: 0.0815 - acc:
1.0000
Epoch 00099: saving model to /content/data/model/weights.epoch_99.hdf5
163/163 [==============================] - 93s 571ms/step - loss: 0.0745 -
acc: 0.9745 - val_loss: 0.0815 - val_acc: 1.0000
Epoch 100/100
162/163 [============================>.] - ETA: 0s - loss: 0.0805 - acc: 0
.9720Epoch 1/100
  1/163 [..............................] - ETA: 56s - loss: 0.0945 - acc:
0.9375
Epoch 00100: saving model to /content/data/model/weights.epoch_100.hdf5
163/163 [==============================] - 92s 564ms/step - loss: 0.0813 -
acc: 0.9716 - val_loss: 0.0945 - val_acc: 0.9375
```

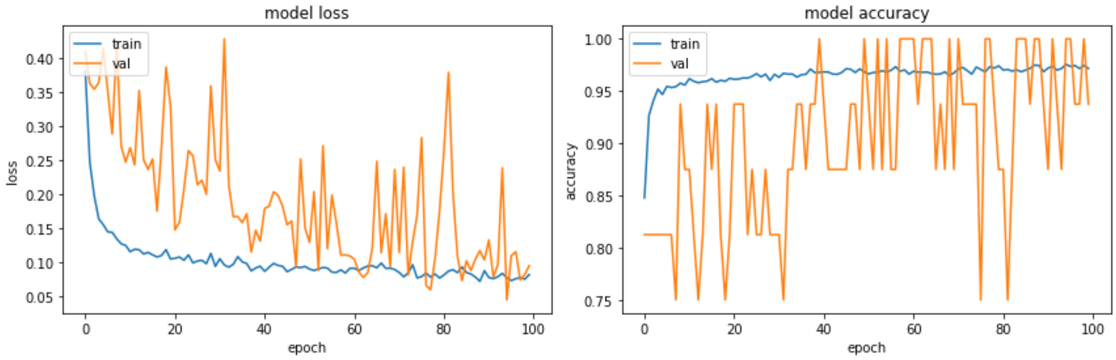
```
import matplotlib.pyplot as plt
def plot_learning_curves(history):
    plt.figure(figsize=(12,4))

    plt.subplot(1,2,1)
    plt.plot(history.history['loss'])
    plt.plot(history.history['val_loss'])
    plt.title('model loss')
    plt.ylabel('loss')
    plt.xlabel('epoch')
    plt.legend(['train', 'val'], loc='upper left')

    plt.subplot(1,2,2)
    plt.plot(history.history['acc'])
    plt.plot(history.history['val_acc'])
    plt.title('model accuracy')
    plt.ylabel('accuracy')
    plt.xlabel('epoch')
    plt.legend(['train', 'val'], loc='upper left')

    plt.tight_layout()
```

```
plot_learning_curves(history)
```



png

```
idx = np.argmin(history.history['val_loss'])
model.load_weights("/content/data/model/weights.epoch_{:02d}.hdf5".format(
idx + 1))

print("Loading the best model")
print("epoch: {}, val_loss: {}, val_acc: {}".format(idx + 1, history.histo
ry['val_loss'][idx], history.history['val_acc'][idx]))
```

```
Loading the best model
epoch: 95, val_loss: 0.04409787803888321, val_acc: 1.0
```

```
test_loss, test_acc = model.evaluate_generator(generator=test_generator, v
erbose=1)
```

```
20/20 [==============================] - 8s 419ms/step - loss: 0.2661 - ac
c: 0.9135
```

```
from sklearn.metrics import accuracy_score, confusion_matrix

test_generator.reset()
test_preds = model.predict_generator(test_generator, verbose=1)
test_preds = np.argmax(test_preds,axis=1)

acc = accuracy_score(test_generator.classes, test_preds)*100
cm = confusion_matrix(test_generator.classes, test_preds)
tn, fp, fn, tp = cm.ravel()

print('CONFUSION MATRIX ------------------')
print(cm)
# plot_confusion_matrix(cm, target_names=['NORMAL', 'PNEUMONIA'], normaliz
e=False)


print('\nTEST METRICS ----------------------')
precision = tp/(tp+fp)*100
recall = tp/(tp+fn)*100
print('Accuracy: {}%'.format(acc))
print('Precision: {}%'.format(precision))
print('Recall: {}%'.format(recall))
```

```
print('F1-score: {}'.format(2*precision*recall/(precision+recall)))

print('\nTRAIN METRIC ----------------------')
print('Train acc: {}%'.format(np.round((history.history['acc'][-1])*100, 1
4)))
```

```
20/20 [==============================] - 8s 390ms/step
CONFUSION MATRIX ------------------
[[197  37]
 [ 17 373]]

TEST METRICS ----------------------
Accuracy: 91.34615384615384%
Precision: 90.97560975609757%
Recall: 95.64102564102565%
F1-score: 93.25

TRAIN METRIC ----------------------
Train acc: 97.16257452964781%
```

9.9 *Appendix I: VGG16 Model 2 Version 2.1.1.0.1*

```
from __future__ import absolute_import, division, print_function, unicode_
literals
import tensorflow as tf

# Extract dataset
import os
import tarfile

import keras_preprocessing
from keras_preprocessing.image import ImageDataGenerator # Data preprocess
ing and augmentation

import sklearn
import numpy as np
```

The default version of TensorFlow in Colab will soon switch to TensorFlow 2.x. We recommend you upgrade now or ensure your notebook will continue to use TensorFlow 1.x via the %tensorflow_version 1.x magic: more info.

```
print(tf.__version__)
```

```
1.15.0
```

```
# Make folder for chest xray data
!mkdir /content/data/

# Make directory to save weights
!mkdir /content/data/model

# Make directory to logs for Tensorboard
!mkdir /content/data/graph

# Download dataset
!wget --no-check-certificate \
    https://s3.eu-central-1.amazonaws.com/public.unit8.co/data/chest_xray.
tar.gz \
    -O /content/data/chest_xray.tar.gz

tar = tarfile.open("data/chest_xray.tar.gz")
tar.extractall(path='./data/')
os.remove('data/chest_xray.tar.gz')
```

```
--2019-10-29 04:15:35--  https://s3.eu-central-1.amazonaws.com/public.unit
8.co/data/chest_xray.tar.gz
Resolving s3.eu-central-1.amazonaws.com (s3.eu-central-1.amazonaws.com)...
52.219.72.111
Connecting to s3.eu-central-1.amazonaws.com (s3.eu-central-1.amazonaws.com
)|52.219.72.111|:443... connected.
HTTP request sent, awaiting response... 200 OK
Length: 1225393795 (1.1G) [application/x-gzip]
Saving to: ‘/content/data/chest_xray.tar.gz’
```

```
/content/data/chest 100%[==================>]   1.14G  26.3MB/s    in 46s

2019-10-29 04:16:22 (25.4 MB/s) - '/content/data/chest_xray.tar.gz' saved
[1225393795/1225393795]
```

Change log: > training_datagen –> ImageDataGenerator

trainable layer –> All except base

24 layers VGG16 model

Optimizer = RMSprop(learning_rate = 0.0001)

loss = categorical_crosscentropy

callback = [checkpoints]

epochs = 100

no class weight balancing

batchsize = 128

```
TRAINING_DIR = "/content/data/chest_xray/train"
VALIDATION_DIR = "/content/data/chest_xray/val"
TEST_DIR = "/content/data/chest_xray/test"

training_datagen = ImageDataGenerator(
    preprocessing_function=tf.keras.applications.vgg16.preprocess_input,
    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,
    # vertical_flip=True
    fill_mode='nearest'
)

validation_datagen = ImageDataGenerator(
    rescale = 1./255
)

test_datagen = ImageDataGenerator(
    rescale = 1./255
)

# Create training data batch
# TODO: Try grayscaling the image to see what will happen
train_generator = training_datagen.flow_from_directory(
    TRAINING_DIR,
    target_size=(150,150),
    class_mode='categorical'
)

validation_generator = validation_datagen.flow_from_directory(
    VALIDATION_DIR,
```

```
    target_size=(150,150),
    class_mode='categorical'
)

test_generator = test_datagen.flow_from_directory(
    TEST_DIR,
    target_size=(150,150),
    class_mode='categorical',
    shuffle=False
)

train_shape = train_generator.image_shape

tf.keras.backend.clear_session() # Destroys the current TF graph and creat
es a new one.

base_model = tf.keras.applications.VGG16(weights='imagenet', include_top=F
alse, input_shape=train_shape)

x = base_model.output
x = tf.keras.layers.Flatten()(x)
x = tf.keras.layers.Dense(64, activation='relu')(x)
x = tf.keras.layers.Dropout(0.33)(x)
x = tf.keras.layers.BatchNormalization()(x)
x = tf.keras.layers.Dense(2, 'softmax')(x)

model = tf.keras.Model(inputs=base_model.input, outputs=x)

# for layer in model.layers[0:20]:
#     layer.trainable = False

for layer in base_model.layers:
  layer.trainable = False

optimizer = tf.keras.optimizers.RMSprop(learning_rate=0.0001) # Lower lear
ning rate by x10

model.compile(loss='categorical_crossentropy',
              optimizer=optimizer,
              metrics=['accuracy'])

# Callbacks stuff
# Function to save the weights of the model after each epoch
checkpoint = tf.keras.callbacks.ModelCheckpoint(
    '/content/data/model/weights.epoch_{epoch:02d}.hdf5',
    monitor='val_accuracy',
    save_best_only=False,
    save_weights_only=False,
    mode='auto',
    verbose=1
)

# Function to stop training early if there's no improvement
early_stopping_monitor = tf.keras.callbacks.EarlyStopping(patience = 3, mo
```

```
nitor = "val_loss", mode="auto", verbose = 1)

lr_reduce = tf.keras.callbacks.ReduceLROnPlateau(monitor='val_loss', facto
r=0.3, patience=2, verbose=1, mode='max')

classweight = sklearn.utils.class_weight.compute_class_weight('balanced',
np.unique(train_generator.labels), train_generator.labels)
print(classweight)

batch_size = 128
epochs = 100

step_size_train = train_generator.n // train_generator.batch_size
step_size_valid = validation_generator.n // validation_generator.batch_siz
e

# Training process
history = model.fit_generator(
    generator=train_generator,
    steps_per_epoch=step_size_train,
    epochs=epochs,
    # callbacks=[early_stopping_monitor],
    callbacks=[checkpoint],
    # shuffle=True,
    validation_data=validation_generator,
    # validation_steps= step_size_valid, #no because it's gonna be 0... if
leave alone its len(generator) which is equal to 1.
    # class_weight=classweight,
    verbose = 1
)

# test_loss, test_acc = model.evaluate_generator(generator=test_generator,
verbose=1)
```

```
Found 5216 images belonging to 2 classes.
Found 16 images belonging to 2 classes.
Found 624 images belonging to 2 classes.
[1.9448173  0.67303226]
Epoch 1/100
162/163 [============================>.] - ETA: 0s - loss: 0.3731 - acc: 0
.8557Epoch 1/100
  1/163 [..............................] - ETA: 4:27 - loss: 0.4169 - acc:
0.9375
Epoch 00001: saving model to /content/data/model/weights.epoch_01.hdf5
163/163 [==============================] - 90s 553ms/step - loss: 0.3734 -
acc: 0.8558 - val_loss: 0.4169 - val_acc: 0.9375
Epoch 2/100
162/163 [============================>.] - ETA: 0s - loss: 0.2292 - acc: 0
.9334Epoch 1/100
  1/163 [..............................] - ETA: 55s - loss: 0.3405 - acc:
0.7500
Epoch 00002: saving model to /content/data/model/weights.epoch_02.hdf5
163/163 [==============================] - 85s 523ms/step - loss: 0.2290 -
acc: 0.9337 - val_loss: 0.3405 - val_acc: 0.7500
```

```
Epoch 3/100
162/163 [============================>.] - ETA: 0s - loss: 0.1887 - acc: 0
.9419Epoch 1/100
  1/163 [..............................] - ETA: 54s - loss: 0.3502 - acc:
0.7500
Epoch 00003: saving model to /content/data/model/weights.epoch_03.hdf5
163/163 [==============================] - 85s 521ms/step - loss: 0.1886 -
acc: 0.9417 - val_loss: 0.3502 - val_acc: 0.7500
Epoch 4/100
162/163 [============================>.] - ETA: 0s - loss: 0.1627 - acc: 0
.9497Epoch 1/100
  1/163 [..............................] - ETA: 52s - loss: 0.4173 - acc:
0.7500
Epoch 00004: saving model to /content/data/model/weights.epoch_04.hdf5
163/163 [==============================] - 84s 516ms/step - loss: 0.1624 -
acc: 0.9498 - val_loss: 0.4173 - val_acc: 0.7500
Epoch 5/100
162/163 [============================>.] - ETA: 0s - loss: 0.1659 - acc: 0
.9450Epoch 1/100
  1/163 [..............................] - ETA: 54s - loss: 0.3685 - acc:
0.8125
Epoch 00005: saving model to /content/data/model/weights.epoch_05.hdf5
163/163 [==============================] - 84s 517ms/step - loss: 0.1656 -
acc: 0.9450 - val_loss: 0.3685 - val_acc: 0.8125
Epoch 6/100
162/163 [============================>.] - ETA: 0s - loss: 0.1529 - acc: 0
.9475Epoch 1/100
  1/163 [..............................] - ETA: 54s - loss: 0.3973 - acc:
0.7500
Epoch 00006: saving model to /content/data/model/weights.epoch_06.hdf5
163/163 [==============================] - 84s 518ms/step - loss: 0.1540 -
acc: 0.9475 - val_loss: 0.3973 - val_acc: 0.7500
Epoch 7/100
162/163 [============================>.] - ETA: 0s - loss: 0.1418 - acc: 0
.9514Epoch 1/100
  1/163 [..............................] - ETA: 56s - loss: 0.6133 - acc:
0.7500
Epoch 00007: saving model to /content/data/model/weights.epoch_07.hdf5
163/163 [==============================] - 86s 525ms/step - loss: 0.1418 -
acc: 0.9515 - val_loss: 0.6133 - val_acc: 0.7500
Epoch 8/100
162/163 [============================>.] - ETA: 0s - loss: 0.1383 - acc: 0
.9510Epoch 1/100
  1/163 [..............................] - ETA: 54s - loss: 0.3999 - acc:
0.9375
Epoch 00008: saving model to /content/data/model/weights.epoch_08.hdf5
163/163 [==============================] - 86s 526ms/step - loss: 0.1382 -
acc: 0.9509 - val_loss: 0.3999 - val_acc: 0.9375
Epoch 9/100
162/163 [============================>.] - ETA: 0s - loss: 0.1304 - acc: 0
.9570Epoch 1/100
  1/163 [..............................] - ETA: 55s - loss: 0.3102 - acc:
0.8125
Epoch 00009: saving model to /content/data/model/weights.epoch_09.hdf5
```

```
163/163 [==============================] - 86s 529ms/step - loss: 0.1304 -
acc: 0.9571 - val_loss: 0.3102 - val_acc: 0.8125
Epoch 10/100
162/163 [============================>.] - ETA: 0s - loss: 0.1297 - acc: 0
.9543Epoch 1/100
  1/163 [..............................] - ETA: 55s - loss: 0.3345 - acc:
0.8125
Epoch 00010: saving model to /content/data/model/weights.epoch_10.hdf5
163/163 [==============================] - 86s 527ms/step - loss: 0.1296 -
acc: 0.9544 - val_loss: 0.3345 - val_acc: 0.8125
Epoch 11/100
162/163 [============================>.] - ETA: 0s - loss: 0.1280 - acc: 0
.9543Epoch 1/100
  1/163 [..............................] - ETA: 57s - loss: 0.3529 - acc:
0.8125
Epoch 00011: saving model to /content/data/model/weights.epoch_11.hdf5
163/163 [==============================] - 86s 529ms/step - loss: 0.1276 -
acc: 0.9544 - val_loss: 0.3529 - val_acc: 0.8125
Epoch 12/100
162/163 [============================>.] - ETA: 0s - loss: 0.1310 - acc: 0
.9512Epoch 1/100
  1/163 [..............................] - ETA: 57s - loss: 0.2507 - acc:
0.8125
Epoch 00012: saving model to /content/data/model/weights.epoch_12.hdf5
163/163 [==============================] - 86s 529ms/step - loss: 0.1310 -
acc: 0.9511 - val_loss: 0.2507 - val_acc: 0.8125
Epoch 13/100
162/163 [============================>.] - ETA: 0s - loss: 0.1306 - acc: 0
.9514Epoch 1/100
  1/163 [..............................] - ETA: 56s - loss: 0.2854 - acc:
0.8125
Epoch 00013: saving model to /content/data/model/weights.epoch_13.hdf5
163/163 [==============================] - 86s 530ms/step - loss: 0.1300 -
acc: 0.9517 - val_loss: 0.2854 - val_acc: 0.8125
Epoch 14/100
162/163 [============================>.] - ETA: 0s - loss: 0.1248 - acc: 0
.9520Epoch 1/100
  1/163 [..............................] - ETA: 54s - loss: 0.3107 - acc:
0.8125
Epoch 00014: saving model to /content/data/model/weights.epoch_14.hdf5
163/163 [==============================] - 86s 528ms/step - loss: 0.1246 -
acc: 0.9523 - val_loss: 0.3107 - val_acc: 0.8125
Epoch 15/100
162/163 [============================>.] - ETA: 0s - loss: 0.1326 - acc: 0
.9518Epoch 1/100
  1/163 [..............................] - ETA: 53s - loss: 0.2202 - acc:
0.9375
Epoch 00015: saving model to /content/data/model/weights.epoch_15.hdf5
163/163 [==============================] - 86s 529ms/step - loss: 0.1324 -
acc: 0.9519 - val_loss: 0.2202 - val_acc: 0.9375
Epoch 16/100
162/163 [============================>.] - ETA: 0s - loss: 0.1229 - acc: 0
.9574Epoch 1/100
  1/163 [..............................] - ETA: 54s - loss: 0.2141 - acc:
```

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0.8750
Epoch 00016: saving model to /content/data/model/weights.epoch_16.hdf5
163/163 [==============================] - 87s 531ms/step - loss: 0.1239 -
acc: 0.9569 - val_loss: 0.2141 - val_acc: 0.8750
Epoch 17/100
162/163 [============================>.] - ETA: 0s - loss: 0.1214 - acc: 0
.9578Epoch 1/100
  1/163 [..............................] - ETA: 54s - loss: 0.3292 - acc:
0.8750
Epoch 00017: saving model to /content/data/model/weights.epoch_17.hdf5
163/163 [==============================] - 87s 531ms/step - loss: 0.1209 -
acc: 0.9580 - val_loss: 0.3292 - val_acc: 0.8750
Epoch 18/100
162/163 [============================>.] - ETA: 0s - loss: 0.1118 - acc: 0
.9610Epoch 1/100
  1/163 [..............................] - ETA: 56s - loss: 0.1904 - acc:
0.9375
Epoch 00018: saving model to /content/data/model/weights.epoch_18.hdf5
163/163 [==============================] - 87s 532ms/step - loss: 0.1134 -
acc: 0.9605 - val_loss: 0.1904 - val_acc: 0.9375
Epoch 19/100
162/163 [============================>.] - ETA: 0s - loss: 0.1073 - acc: 0
.9605Epoch 1/100
  1/163 [..............................] - ETA: 54s - loss: 0.2356 - acc:
0.8125
Epoch 00019: saving model to /content/data/model/weights.epoch_19.hdf5
163/163 [==============================] - 89s 544ms/step - loss: 0.1079 -
acc: 0.9603 - val_loss: 0.2356 - val_acc: 0.8125
Epoch 20/100
162/163 [============================>.] - ETA: 0s - loss: 0.1264 - acc: 0
.9576Epoch 1/100
  1/163 [..............................] - ETA: 57s - loss: 0.2328 - acc:
0.8125
Epoch 00020: saving model to /content/data/model/weights.epoch_20.hdf5
163/163 [==============================] - 89s 549ms/step - loss: 0.1261 -
acc: 0.9576 - val_loss: 0.2328 - val_acc: 0.8125
Epoch 21/100
162/163 [============================>.] - ETA: 0s - loss: 0.1082 - acc: 0
.9620Epoch 1/100
  1/163 [..............................] - ETA: 56s - loss: 0.2988 - acc:
0.8750
Epoch 00021: saving model to /content/data/model/weights.epoch_21.hdf5
163/163 [==============================] - 88s 539ms/step - loss: 0.1083 -
acc: 0.9618 - val_loss: 0.2988 - val_acc: 0.8750
Epoch 22/100
162/163 [============================>.] - ETA: 0s - loss: 0.1160 - acc: 0
.9587Epoch 1/100
  1/163 [..............................] - ETA: 57s - loss: 0.4808 - acc:
0.7500
Epoch 00022: saving model to /content/data/model/weights.epoch_22.hdf5
163/163 [==============================] - 88s 542ms/step - loss: 0.1155 -
acc: 0.9590 - val_loss: 0.4808 - val_acc: 0.7500
Epoch 23/100
162/163 [============================>.] - ETA: 0s - loss: 0.1138 - acc: 0
```

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.9587Epoch 1/100
  1/163 [..............................] - ETA: 1:01 - loss: 0.3481 - acc:
0.8750
Epoch 00023: saving model to /content/data/model/weights.epoch_23.hdf5
163/163 [==============================] - 92s 562ms/step - loss: 0.1140 -
acc: 0.9588 - val_loss: 0.3481 - val_acc: 0.8750
Epoch 24/100
162/163 [============================>.] - ETA: 0s - loss: 0.1029 - acc: 0
.9620Epoch 1/100
  1/163 [..............................] - ETA: 57s - loss: 0.5066 - acc:
0.7500
Epoch 00024: saving model to /content/data/model/weights.epoch_24.hdf5
163/163 [==============================] - 92s 565ms/step - loss: 0.1027 -
acc: 0.9620 - val_loss: 0.5066 - val_acc: 0.7500
Epoch 25/100
162/163 [============================>.] - ETA: 0s - loss: 0.1052 - acc: 0
.9633Epoch 1/100
  1/163 [..............................] - ETA: 58s - loss: 0.2796 - acc:
0.9375
Epoch 00025: saving model to /content/data/model/weights.epoch_25.hdf5
163/163 [==============================] - 92s 563ms/step - loss: 0.1056 -
acc: 0.9632 - val_loss: 0.2796 - val_acc: 0.9375
Epoch 26/100
162/163 [============================>.] - ETA: 0s - loss: 0.1152 - acc: 0
.9610Epoch 1/100
  1/163 [..............................] - ETA: 56s - loss: 0.4961 - acc:
0.7500
Epoch 00026: saving model to /content/data/model/weights.epoch_26.hdf5
163/163 [==============================] - 93s 570ms/step - loss: 0.1148 -
acc: 0.9613 - val_loss: 0.4961 - val_acc: 0.7500
Epoch 27/100
162/163 [============================>.] - ETA: 0s - loss: 0.1080 - acc: 0
.9612Epoch 1/100
  1/163 [..............................] - ETA: 59s - loss: 0.4943 - acc:
0.7500
Epoch 00027: saving model to /content/data/model/weights.epoch_27.hdf5
163/163 [==============================] - 92s 567ms/step - loss: 0.1077 -
acc: 0.9613 - val_loss: 0.4943 - val_acc: 0.7500
Epoch 28/100
162/163 [============================>.] - ETA: 0s - loss: 0.1023 - acc: 0
.9672Epoch 1/100
  1/163 [..............................] - ETA: 57s - loss: 0.2127 - acc:
0.8125
Epoch 00028: saving model to /content/data/model/weights.epoch_28.hdf5
163/163 [==============================] - 92s 563ms/step - loss: 0.1021 -
acc: 0.9674 - val_loss: 0.2127 - val_acc: 0.8125
Epoch 29/100
162/163 [============================>.] - ETA: 0s - loss: 0.1045 - acc: 0
.9618Epoch 1/100
  1/163 [..............................] - ETA: 1:00 - loss: 0.2548 - acc:
0.9375
Epoch 00029: saving model to /content/data/model/weights.epoch_29.hdf5
163/163 [==============================] - 92s 566ms/step - loss: 0.1047 -
acc: 0.9618 - val_loss: 0.2548 - val_acc: 0.9375
```

```
Epoch 30/100
162/163 [============================>.] - ETA: 0s - loss: 0.1055 - acc: 0
.9599Epoch 1/100
  1/163 [..............................] - ETA: 1:00 - loss: 0.4053 - acc:
0.8125
Epoch 00030: saving model to /content/data/model/weights.epoch_30.hdf5
163/163 [==============================] - 92s 565ms/step - loss: 0.1060 -
acc: 0.9597 - val_loss: 0.4053 - val_acc: 0.8125
Epoch 31/100
162/163 [============================>.] - ETA: 0s - loss: 0.1066 - acc: 0
.9632Epoch 1/100
  1/163 [..............................] - ETA: 57s - loss: 0.5711 - acc:
0.6875
Epoch 00031: saving model to /content/data/model/weights.epoch_31.hdf5
163/163 [==============================] - 91s 561ms/step - loss: 0.1077 -
acc: 0.9630 - val_loss: 0.5711 - val_acc: 0.6875
Epoch 32/100
162/163 [============================>.] - ETA: 0s - loss: 0.1058 - acc: 0
.9651Epoch 1/100
  1/163 [..............................] - ETA: 58s - loss: 0.4007 - acc:
0.8750
Epoch 00032: saving model to /content/data/model/weights.epoch_32.hdf5
163/163 [==============================] - 93s 571ms/step - loss: 0.1060 -
acc: 0.9651 - val_loss: 0.4007 - val_acc: 0.8750
Epoch 33/100
162/163 [============================>.] - ETA: 0s - loss: 0.1109 - acc: 0
.9591Epoch 1/100
  1/163 [..............................] - ETA: 1:02 - loss: 0.2471 - acc:
0.8125
Epoch 00033: saving model to /content/data/model/weights.epoch_33.hdf5
163/163 [==============================] - 92s 566ms/step - loss: 0.1105 -
acc: 0.9592 - val_loss: 0.2471 - val_acc: 0.8125
Epoch 34/100
162/163 [============================>.] - ETA: 0s - loss: 0.1022 - acc: 0
.9626Epoch 1/100
  1/163 [..............................] - ETA: 57s - loss: 0.1648 - acc:
0.9375
Epoch 00034: saving model to /content/data/model/weights.epoch_34.hdf5
163/163 [==============================] - 92s 564ms/step - loss: 0.1025 -
acc: 0.9624 - val_loss: 0.1648 - val_acc: 0.9375
Epoch 35/100
162/163 [============================>.] - ETA: 0s - loss: 0.1010 - acc: 0
.9682Epoch 1/100
  1/163 [..............................] - ETA: 56s - loss: 0.3858 - acc:
0.7500
Epoch 00035: saving model to /content/data/model/weights.epoch_35.hdf5
163/163 [==============================] - 92s 565ms/step - loss: 0.1007 -
acc: 0.9684 - val_loss: 0.3858 - val_acc: 0.7500
Epoch 36/100
162/163 [============================>.] - ETA: 0s - loss: 0.1065 - acc: 0
.9612Epoch 1/100
  1/163 [..............................] - ETA: 59s - loss: 0.2015 - acc:
0.8125
Epoch 00036: saving model to /content/data/model/weights.epoch_36.hdf5
```

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163/163 [==============================] - 92s 566ms/step - loss: 0.1060 -
acc: 0.9615 - val_loss: 0.2015 - val_acc: 0.8125
Epoch 37/100
162/163 [============================>.] - ETA: 0s - loss: 0.1044 - acc: 0
.9620Epoch 1/100
  1/163 [..............................] - ETA: 57s - loss: 0.3078 - acc:
0.8750
Epoch 00037: saving model to /content/data/model/weights.epoch_37.hdf5
163/163 [==============================] - 92s 567ms/step - loss: 0.1061 -
acc: 0.9615 - val_loss: 0.3078 - val_acc: 0.8750
Epoch 38/100
162/163 [============================>.] - ETA: 0s - loss: 0.0994 - acc: 0
.9641Epoch 1/100
  1/163 [..............................] - ETA: 1:01 - loss: 0.4050 - acc:
0.7500
Epoch 00038: saving model to /content/data/model/weights.epoch_38.hdf5
163/163 [==============================] - 92s 564ms/step - loss: 0.1000 -
acc: 0.9640 - val_loss: 0.4050 - val_acc: 0.7500
Epoch 39/100
162/163 [============================>.] - ETA: 0s - loss: 0.0972 - acc: 0
.9645Epoch 1/100
  1/163 [..............................] - ETA: 56s - loss: 0.4122 - acc:
0.6875
Epoch 00039: saving model to /content/data/model/weights.epoch_39.hdf5
163/163 [==============================] - 92s 565ms/step - loss: 0.0975 -
acc: 0.9645 - val_loss: 0.4122 - val_acc: 0.6875
Epoch 40/100
162/163 [============================>.] - ETA: 0s - loss: 0.0988 - acc: 0
.9643Epoch 1/100
  1/163 [..............................] - ETA: 57s - loss: 0.2440 - acc:
0.8125
Epoch 00040: saving model to /content/data/model/weights.epoch_40.hdf5
163/163 [==============================] - 92s 566ms/step - loss: 0.0986 -
acc: 0.9643 - val_loss: 0.2440 - val_acc: 0.8125
Epoch 41/100
162/163 [============================>.] - ETA: 0s - loss: 0.1052 - acc: 0
.9651Epoch 1/100
  1/163 [..............................] - ETA: 56s - loss: 0.3317 - acc:
0.8125
Epoch 00041: saving model to /content/data/model/weights.epoch_41.hdf5
163/163 [==============================] - 92s 567ms/step - loss: 0.1055 -
acc: 0.9649 - val_loss: 0.3317 - val_acc: 0.8125
Epoch 42/100
162/163 [============================>.] - ETA: 0s - loss: 0.1019 - acc: 0
.9641Epoch 1/100
  1/163 [..............................] - ETA: 55s - loss: 0.1347 - acc:
0.9375
Epoch 00042: saving model to /content/data/model/weights.epoch_42.hdf5
163/163 [==============================] - 92s 563ms/step - loss: 0.1015 -
acc: 0.9641 - val_loss: 0.1347 - val_acc: 0.9375
Epoch 43/100
162/163 [============================>.] - ETA: 0s - loss: 0.0979 - acc: 0
.9641Epoch 1/100
  1/163 [..............................] - ETA: 55s - loss: 0.2481 - acc:
```

```
0.8750
Epoch 00043: saving model to /content/data/model/weights.epoch_43.hdf5
163/163 [==============================] - 92s 564ms/step - loss: 0.0983 -
acc: 0.9640 - val_loss: 0.2481 - val_acc: 0.8750
Epoch 44/100
162/163 [============================>.] - ETA: 0s - loss: 0.0962 - acc: 0
.9686Epoch 1/100
  1/163 [..............................] - ETA: 57s - loss: 0.1823 - acc:
0.8750
Epoch 00044: saving model to /content/data/model/weights.epoch_44.hdf5
163/163 [==============================] - 92s 563ms/step - loss: 0.0957 -
acc: 0.9688 - val_loss: 0.1823 - val_acc: 0.8750
Epoch 45/100
162/163 [============================>.] - ETA: 0s - loss: 0.0857 - acc: 0
.9689Epoch 1/100
  1/163 [..............................] - ETA: 58s - loss: 0.2455 - acc:
0.8750
Epoch 00045: saving model to /content/data/model/weights.epoch_45.hdf5
163/163 [==============================] - 91s 561ms/step - loss: 0.0858 -
acc: 0.9688 - val_loss: 0.2455 - val_acc: 0.8750
Epoch 46/100
162/163 [============================>.] - ETA: 0s - loss: 0.1046 - acc: 0
.9659Epoch 1/100
  1/163 [..............................] - ETA: 56s - loss: 0.2159 - acc:
0.8750
Epoch 00046: saving model to /content/data/model/weights.epoch_46.hdf5
163/163 [==============================] - 92s 565ms/step - loss: 0.1047 -
acc: 0.9657 - val_loss: 0.2159 - val_acc: 0.8750
Epoch 47/100
162/163 [============================>.] - ETA: 0s - loss: 0.1057 - acc: 0
.9626Epoch 1/100
  1/163 [..............................] - ETA: 59s - loss: 0.2620 - acc:
0.8125
Epoch 00047: saving model to /content/data/model/weights.epoch_47.hdf5
163/163 [==============================] - 91s 558ms/step - loss: 0.1052 -
acc: 0.9628 - val_loss: 0.2620 - val_acc: 0.8125
Epoch 48/100
162/163 [============================>.] - ETA: 0s - loss: 0.1008 - acc: 0
.9662Epoch 1/100
  1/163 [..............................] - ETA: 1:03 - loss: 0.2468 - acc:
0.8750
Epoch 00048: saving model to /content/data/model/weights.epoch_48.hdf5
163/163 [==============================] - 91s 560ms/step - loss: 0.1020 -
acc: 0.9657 - val_loss: 0.2468 - val_acc: 0.8750
Epoch 49/100
162/163 [============================>.] - ETA: 0s - loss: 0.0892 - acc: 0
.9680Epoch 1/100
  1/163 [..............................] - ETA: 56s - loss: 0.5087 - acc:
0.6875
Epoch 00049: saving model to /content/data/model/weights.epoch_49.hdf5
163/163 [==============================] - 91s 561ms/step - loss: 0.0893 -
acc: 0.9678 - val_loss: 0.5087 - val_acc: 0.6875
Epoch 50/100
162/163 [============================>.] - ETA: 0s - loss: 0.1011 - acc: 0
```

```
.9676Epoch 1/100
  1/163 [..............................] - ETA: 58s - loss: 0.2828 - acc:
0.8125
Epoch 00050: saving model to /content/data/model/weights.epoch_50.hdf5
163/163 [==============================] - 91s 560ms/step - loss: 0.1010 -
acc: 0.9676 - val_loss: 0.2828 - val_acc: 0.8125
Epoch 51/100
162/163 [============================>.] - ETA: 0s - loss: 0.0929 - acc: 0
.9672Epoch 1/100
  1/163 [..............................] - ETA: 55s - loss: 0.1985 - acc:
0.8750
Epoch 00051: saving model to /content/data/model/weights.epoch_51.hdf5
163/163 [==============================] - 92s 565ms/step - loss: 0.0928 -
acc: 0.9672 - val_loss: 0.1985 - val_acc: 0.8750
Epoch 52/100
162/163 [============================>.] - ETA: 0s - loss: 0.1020 - acc: 0
.9641Epoch 1/100
  1/163 [..............................] - ETA: 1:01 - loss: 0.2546 - acc:
0.8125
Epoch 00052: saving model to /content/data/model/weights.epoch_52.hdf5
163/163 [==============================] - 92s 564ms/step - loss: 0.1020 -
acc: 0.9641 - val_loss: 0.2546 - val_acc: 0.8125
Epoch 53/100
162/163 [============================>.] - ETA: 0s - loss: 0.0939 - acc: 0
.9674Epoch 1/100
  1/163 [..............................] - ETA: 59s - loss: 0.1982 - acc:
0.8750
Epoch 00053: saving model to /content/data/model/weights.epoch_53.hdf5
163/163 [==============================] - 92s 564ms/step - loss: 0.0935 -
acc: 0.9676 - val_loss: 0.1982 - val_acc: 0.8750
Epoch 54/100
162/163 [============================>.] - ETA: 0s - loss: 0.0957 - acc: 0
.9645Epoch 1/100
  1/163 [..............................] - ETA: 56s - loss: 0.3821 - acc:
0.8125
Epoch 00054: saving model to /content/data/model/weights.epoch_54.hdf5
163/163 [==============================] - 92s 566ms/step - loss: 0.0956 -
acc: 0.9643 - val_loss: 0.3821 - val_acc: 0.8125
Epoch 55/100
162/163 [============================>.] - ETA: 0s - loss: 0.0941 - acc: 0
.9682Epoch 1/100
  1/163 [..............................] - ETA: 57s - loss: 0.1872 - acc:
0.9375
Epoch 00055: saving model to /content/data/model/weights.epoch_55.hdf5
163/163 [==============================] - 92s 562ms/step - loss: 0.0948 -
acc: 0.9680 - val_loss: 0.1872 - val_acc: 0.9375
Epoch 56/100
162/163 [============================>.] - ETA: 0s - loss: 0.0983 - acc: 0
.9643Epoch 1/100
  1/163 [..............................] - ETA: 57s - loss: 0.1748 - acc:
0.9375
Epoch 00056: saving model to /content/data/model/weights.epoch_56.hdf5
163/163 [==============================] - 92s 563ms/step - loss: 0.0979 -
acc: 0.9645 - val_loss: 0.1748 - val_acc: 0.9375
```

```
Epoch 57/100
162/163 [============================>.] - ETA: 0s - loss: 0.0899 - acc: 0
.9689Epoch 1/100
  1/163 [..............................] - ETA: 1:02 - loss: 0.1884 - acc:
0.8125
Epoch 00057: saving model to /content/data/model/weights.epoch_57.hdf5
163/163 [==============================] - 93s 569ms/step - loss: 0.0915 -
acc: 0.9684 - val_loss: 0.1884 - val_acc: 0.8125
Epoch 58/100
162/163 [============================>.] - ETA: 0s - loss: 0.0974 - acc: 0
.9653Epoch 1/100
  1/163 [..............................] - ETA: 58s - loss: 0.2093 - acc:
0.8750
Epoch 00058: saving model to /content/data/model/weights.epoch_58.hdf5
163/163 [==============================] - 92s 561ms/step - loss: 0.0973 -
acc: 0.9651 - val_loss: 0.2093 - val_acc: 0.8750
Epoch 59/100
162/163 [============================>.] - ETA: 0s - loss: 0.0914 - acc: 0
.9674Epoch 1/100
  1/163 [..............................] - ETA: 1:08 - loss: 0.2185 - acc:
0.8750
Epoch 00059: saving model to /content/data/model/weights.epoch_59.hdf5
163/163 [==============================] - 92s 566ms/step - loss: 0.0918 -
acc: 0.9674 - val_loss: 0.2185 - val_acc: 0.8750
Epoch 60/100
162/163 [============================>.] - ETA: 0s - loss: 0.0880 - acc: 0
.9697Epoch 1/100
  1/163 [..............................] - ETA: 57s - loss: 0.1639 - acc:
0.9375
Epoch 00060: saving model to /content/data/model/weights.epoch_60.hdf5
163/163 [==============================] - 92s 563ms/step - loss: 0.0877 -
acc: 0.9697 - val_loss: 0.1639 - val_acc: 0.9375
Epoch 61/100
162/163 [============================>.] - ETA: 0s - loss: 0.0932 - acc: 0
.9676Epoch 1/100
  1/163 [..............................] - ETA: 57s - loss: 0.1833 - acc:
0.8750
Epoch 00061: saving model to /content/data/model/weights.epoch_61.hdf5
163/163 [==============================] - 92s 563ms/step - loss: 0.0939 -
acc: 0.9670 - val_loss: 0.1833 - val_acc: 0.8750
Epoch 62/100
162/163 [============================>.] - ETA: 0s - loss: 0.0989 - acc: 0
.9637Epoch 1/100
  1/163 [..............................] - ETA: 59s - loss: 0.4403 - acc:
0.7500
Epoch 00062: saving model to /content/data/model/weights.epoch_62.hdf5
163/163 [==============================] - 92s 565ms/step - loss: 0.0985 -
acc: 0.9640 - val_loss: 0.4403 - val_acc: 0.7500
Epoch 63/100
162/163 [============================>.] - ETA: 0s - loss: 0.0908 - acc: 0
.9705Epoch 1/100
  1/163 [..............................] - ETA: 57s - loss: 0.2128 - acc:
0.8750
Epoch 00063: saving model to /content/data/model/weights.epoch_63.hdf5
```

```
163/163 [==============================] - 91s 561ms/step - loss: 0.0915 -
acc: 0.9705 - val_loss: 0.2128 - val_acc: 0.8750
Epoch 64/100
162/163 [============================>.] - ETA: 0s - loss: 0.0974 - acc: 0
.9647Epoch 1/100
  1/163 [..............................] - ETA: 56s - loss: 0.1410 - acc:
0.9375
Epoch 00064: saving model to /content/data/model/weights.epoch_64.hdf5
163/163 [==============================] - 93s 568ms/step - loss: 0.0975 -
acc: 0.9647 - val_loss: 0.1410 - val_acc: 0.9375
Epoch 65/100
162/163 [============================>.] - ETA: 0s - loss: 0.0910 - acc: 0
.9695Epoch 1/100
  1/163 [..............................] - ETA: 57s - loss: 0.1505 - acc:
0.9375
Epoch 00065: saving model to /content/data/model/weights.epoch_65.hdf5
163/163 [==============================] - 92s 563ms/step - loss: 0.0910 -
acc: 0.9693 - val_loss: 0.1505 - val_acc: 0.9375
Epoch 66/100
162/163 [============================>.] - ETA: 0s - loss: 0.0902 - acc: 0
.9682Epoch 1/100
  1/163 [..............................] - ETA: 58s - loss: 0.1599 - acc:
0.9375
Epoch 00066: saving model to /content/data/model/weights.epoch_66.hdf5
163/163 [==============================] - 92s 564ms/step - loss: 0.0905 -
acc: 0.9680 - val_loss: 0.1599 - val_acc: 0.9375
Epoch 67/100
162/163 [============================>.] - ETA: 0s - loss: 0.0929 - acc: 0
.9674Epoch 1/100
  1/163 [..............................] - ETA: 1:00 - loss: 0.1942 - acc:
0.8750
Epoch 00067: saving model to /content/data/model/weights.epoch_67.hdf5
163/163 [==============================] - 92s 565ms/step - loss: 0.0927 -
acc: 0.9676 - val_loss: 0.1942 - val_acc: 0.8750
Epoch 68/100
162/163 [============================>.] - ETA: 0s - loss: 0.0899 - acc: 0
.9705Epoch 1/100
  1/163 [..............................] - ETA: 59s - loss: 0.2455 - acc:
0.8750
Epoch 00068: saving model to /content/data/model/weights.epoch_68.hdf5
163/163 [==============================] - 92s 561ms/step - loss: 0.0897 -
acc: 0.9705 - val_loss: 0.2455 - val_acc: 0.8750
Epoch 69/100
162/163 [============================>.] - ETA: 0s - loss: 0.0955 - acc: 0
.9659Epoch 1/100
  1/163 [..............................] - ETA: 59s - loss: 0.1850 - acc:
0.9375
Epoch 00069: saving model to /content/data/model/weights.epoch_69.hdf5
163/163 [==============================] - 92s 567ms/step - loss: 0.0955 -
acc: 0.9657 - val_loss: 0.1850 - val_acc: 0.9375
Epoch 70/100
162/163 [============================>.] - ETA: 0s - loss: 0.0820 - acc: 0
.9716Epoch 1/100
  1/163 [..............................] - ETA: 58s - loss: 0.3135 - acc:
```

```
0.8125
Epoch 00070: saving model to /content/data/model/weights.epoch_70.hdf5
163/163 [==============================] - 92s 564ms/step - loss: 0.0819 -
acc: 0.9716 - val_loss: 0.3135 - val_acc: 0.8125
Epoch 71/100
162/163 [============================>.] - ETA: 0s - loss: 0.0924 - acc: 0
.9691Epoch 1/100
  1/163 [..............................] - ETA: 1:01 - loss: 0.1686 - acc:
0.8750
Epoch 00071: saving model to /content/data/model/weights.epoch_71.hdf5
163/163 [==============================] - 92s 567ms/step - loss: 0.0921 -
acc: 0.9693 - val_loss: 0.1686 - val_acc: 0.8750
Epoch 72/100
162/163 [============================>.] - ETA: 0s - loss: 0.0958 - acc: 0
.9655Epoch 1/100
  1/163 [..............................] - ETA: 1:00 - loss: 0.3796 - acc:
0.7500
Epoch 00072: saving model to /content/data/model/weights.epoch_72.hdf5
163/163 [==============================] - 93s 570ms/step - loss: 0.0958 -
acc: 0.9655 - val_loss: 0.3796 - val_acc: 0.7500
Epoch 73/100
162/163 [============================>.] - ETA: 0s - loss: 0.0947 - acc: 0
.9686Epoch 1/100
  1/163 [..............................] - ETA: 57s - loss: 0.1221 - acc:
0.9375
Epoch 00073: saving model to /content/data/model/weights.epoch_73.hdf5
163/163 [==============================] - 93s 568ms/step - loss: 0.0944 -
acc: 0.9688 - val_loss: 0.1221 - val_acc: 0.9375
Epoch 74/100
162/163 [============================>.] - ETA: 0s - loss: 0.0908 - acc: 0
.9703Epoch 1/100
  1/163 [..............................] - ETA: 58s - loss: 0.1438 - acc:
0.9375
Epoch 00074: saving model to /content/data/model/weights.epoch_74.hdf5
163/163 [==============================] - 92s 565ms/step - loss: 0.0908 -
acc: 0.9703 - val_loss: 0.1438 - val_acc: 0.9375
Epoch 75/100
162/163 [============================>.] - ETA: 0s - loss: 0.0881 - acc: 0
.9707Epoch 1/100
  1/163 [..............................] - ETA: 58s - loss: 0.1826 - acc:
0.8750
Epoch 00075: saving model to /content/data/model/weights.epoch_75.hdf5
163/163 [==============================] - 91s 560ms/step - loss: 0.0878 -
acc: 0.9709 - val_loss: 0.1826 - val_acc: 0.8750
Epoch 76/100
162/163 [============================>.] - ETA: 0s - loss: 0.0941 - acc: 0
.9682Epoch 1/100
  1/163 [..............................] - ETA: 57s - loss: 0.1326 - acc:
0.9375
Epoch 00076: saving model to /content/data/model/weights.epoch_76.hdf5
163/163 [==============================] - 93s 569ms/step - loss: 0.0939 -
acc: 0.9680 - val_loss: 0.1326 - val_acc: 0.9375
Epoch 77/100
162/163 [============================>.] - ETA: 0s - loss: 0.0877 - acc: 0
```

```
.9688Epoch 1/100
  1/163 [..............................] - ETA: 57s - loss: 0.1591 - acc:
0.8750
Epoch 00077: saving model to /content/data/model/weights.epoch_77.hdf5
163/163 [==============================] - 92s 565ms/step - loss: 0.0875 -
acc: 0.9688 - val_loss: 0.1591 - val_acc: 0.8750
Epoch 78/100
162/163 [============================>.] - ETA: 0s - loss: 0.0957 - acc: 0
.9682Epoch 1/100
  1/163 [..............................] - ETA: 1:01 - loss: 0.1860 - acc:
0.8750
Epoch 00078: saving model to /content/data/model/weights.epoch_78.hdf5
163/163 [==============================] - 92s 563ms/step - loss: 0.0966 -
acc: 0.9680 - val_loss: 0.1860 - val_acc: 0.8750
Epoch 79/100
162/163 [============================>.] - ETA: 0s - loss: 0.1010 - acc: 0
.9618Epoch 1/100
  1/163 [..............................] - ETA: 57s - loss: 0.2063 - acc:
0.8125
Epoch 00079: saving model to /content/data/model/weights.epoch_79.hdf5
163/163 [==============================] - 92s 567ms/step - loss: 0.1009 -
acc: 0.9618 - val_loss: 0.2063 - val_acc: 0.8125
Epoch 80/100
162/163 [============================>.] - ETA: 0s - loss: 0.0910 - acc: 0
.9674Epoch 1/100
  1/163 [..............................] - ETA: 59s - loss: 0.3628 - acc:
0.7500
Epoch 00080: saving model to /content/data/model/weights.epoch_80.hdf5
163/163 [==============================] - 92s 563ms/step - loss: 0.0905 -
acc: 0.9676 - val_loss: 0.3628 - val_acc: 0.7500
Epoch 81/100
162/163 [============================>.] - ETA: 0s - loss: 0.0833 - acc: 0
.9705Epoch 1/100
  1/163 [..............................] - ETA: 57s - loss: 0.1777 - acc:
0.9375
Epoch 00081: saving model to /content/data/model/weights.epoch_81.hdf5
163/163 [==============================] - 93s 569ms/step - loss: 0.0836 -
acc: 0.9703 - val_loss: 0.1777 - val_acc: 0.9375
Epoch 82/100
162/163 [============================>.] - ETA: 0s - loss: 0.0895 - acc: 0
.9691Epoch 1/100
  1/163 [..............................] - ETA: 1:00 - loss: 0.1777 - acc:
0.9375
Epoch 00082: saving model to /content/data/model/weights.epoch_82.hdf5
163/163 [==============================] - 92s 563ms/step - loss: 0.0891 -
acc: 0.9693 - val_loss: 0.1777 - val_acc: 0.9375
Epoch 83/100
162/163 [============================>.] - ETA: 0s - loss: 0.0890 - acc: 0
.9680Epoch 1/100
  1/163 [..............................] - ETA: 57s - loss: 0.2701 - acc:
0.8125
Epoch 00083: saving model to /content/data/model/weights.epoch_83.hdf5
163/163 [==============================] - 92s 566ms/step - loss: 0.0887 -
acc: 0.9680 - val_loss: 0.2701 - val_acc: 0.8125
```

```
Epoch 84/100
162/163 [============================>.] - ETA: 0s - loss: 0.0830 - acc: 0
.9718Epoch 1/100
  1/163 [..............................] - ETA: 58s - loss: 0.1363 - acc:
0.9375
Epoch 00084: saving model to /content/data/model/weights.epoch_84.hdf5
163/163 [==============================] - 93s 571ms/step - loss: 0.0830 -
acc: 0.9716 - val_loss: 0.1363 - val_acc: 0.9375
Epoch 85/100
162/163 [============================>.] - ETA: 0s - loss: 0.0862 - acc: 0
.9693Epoch 1/100
  1/163 [..............................] - ETA: 1:00 - loss: 0.1144 - acc:
1.0000
Epoch 00085: saving model to /content/data/model/weights.epoch_85.hdf5
163/163 [==============================] - 93s 572ms/step - loss: 0.0864 -
acc: 0.9689 - val_loss: 0.1144 - val_acc: 1.0000
Epoch 86/100
162/163 [============================>.] - ETA: 0s - loss: 0.0909 - acc: 0
.9659Epoch 1/100
  1/163 [..............................] - ETA: 57s - loss: 0.2144 - acc:
0.8750
Epoch 00086: saving model to /content/data/model/weights.epoch_86.hdf5
163/163 [==============================] - 93s 568ms/step - loss: 0.0906 -
acc: 0.9661 - val_loss: 0.2144 - val_acc: 0.8750
Epoch 87/100
162/163 [============================>.] - ETA: 0s - loss: 0.0855 - acc: 0
.9701Epoch 1/100
  1/163 [..............................] - ETA: 58s - loss: 0.1609 - acc:
0.9375
Epoch 00087: saving model to /content/data/model/weights.epoch_87.hdf5
163/163 [==============================] - 92s 567ms/step - loss: 0.0852 -
acc: 0.9703 - val_loss: 0.1609 - val_acc: 0.9375
Epoch 88/100
162/163 [============================>.] - ETA: 0s - loss: 0.0844 - acc: 0
.9701Epoch 1/100
  1/163 [..............................] - ETA: 1:04 - loss: 0.1537 - acc:
0.9375
Epoch 00088: saving model to /content/data/model/weights.epoch_88.hdf5
163/163 [==============================] - 93s 569ms/step - loss: 0.0845 -
acc: 0.9697 - val_loss: 0.1537 - val_acc: 0.9375
Epoch 89/100
162/163 [============================>.] - ETA: 0s - loss: 0.0876 - acc: 0
.9680Epoch 1/100
  1/163 [..............................] - ETA: 56s - loss: 0.3423 - acc:
0.7500
Epoch 00089: saving model to /content/data/model/weights.epoch_89.hdf5
163/163 [==============================] - 92s 566ms/step - loss: 0.0874 -
acc: 0.9680 - val_loss: 0.3423 - val_acc: 0.7500
Epoch 90/100
162/163 [============================>.] - ETA: 0s - loss: 0.0867 - acc: 0
.9689Epoch 1/100
  1/163 [..............................] - ETA: 58s - loss: 0.0911 - acc:
1.0000
Epoch 00090: saving model to /content/data/model/weights.epoch_90.hdf5
```

```
163/163 [==============================] - 92s 563ms/step - loss: 0.0871 -
acc: 0.9689 - val_loss: 0.0911 - val_acc: 1.0000
Epoch 91/100
162/163 [============================>.] - ETA: 0s - loss: 0.0884 - acc: 0
.9688Epoch 1/100
  1/163 [..............................] - ETA: 59s - loss: 0.1374 - acc:
0.9375
Epoch 00091: saving model to /content/data/model/weights.epoch_91.hdf5
163/163 [==============================] - 92s 564ms/step - loss: 0.0884 -
acc: 0.9688 - val_loss: 0.1374 - val_acc: 0.9375
Epoch 92/100
162/163 [============================>.] - ETA: 0s - loss: 0.0960 - acc: 0
.9678Epoch 1/100
  1/163 [..............................] - ETA: 54s - loss: 0.1169 - acc:
0.9375
Epoch 00092: saving model to /content/data/model/weights.epoch_92.hdf5
163/163 [==============================] - 92s 567ms/step - loss: 0.0956 -
acc: 0.9680 - val_loss: 0.1169 - val_acc: 0.9375
Epoch 93/100
162/163 [============================>.] - ETA: 0s - loss: 0.0969 - acc: 0
.9662Epoch 1/100
  1/163 [..............................] - ETA: 1:00 - loss: 0.1792 - acc:
0.9375
Epoch 00093: saving model to /content/data/model/weights.epoch_93.hdf5
163/163 [==============================] - 92s 562ms/step - loss: 0.0965 -
acc: 0.9664 - val_loss: 0.1792 - val_acc: 0.9375
Epoch 94/100
162/163 [============================>.] - ETA: 0s - loss: 0.0866 - acc: 0
.9701Epoch 1/100
  1/163 [..............................] - ETA: 1:01 - loss: 0.1591 - acc:
0.9375
Epoch 00094: saving model to /content/data/model/weights.epoch_94.hdf5
163/163 [==============================] - 92s 565ms/step - loss: 0.0868 -
acc: 0.9697 - val_loss: 0.1591 - val_acc: 0.9375
Epoch 95/100
162/163 [============================>.] - ETA: 0s - loss: 0.0883 - acc: 0
.9699Epoch 1/100
  1/163 [..............................] - ETA: 1:00 - loss: 0.1322 - acc:
0.9375
Epoch 00095: saving model to /content/data/model/weights.epoch_95.hdf5
163/163 [==============================] - 92s 567ms/step - loss: 0.0884 -
acc: 0.9699 - val_loss: 0.1322 - val_acc: 0.9375
Epoch 96/100
162/163 [============================>.] - ETA: 0s - loss: 0.0869 - acc: 0
.9670Epoch 1/100
  1/163 [..............................] - ETA: 59s - loss: 0.1446 - acc:
0.9375
Epoch 00096: saving model to /content/data/model/weights.epoch_96.hdf5
163/163 [==============================] - 93s 568ms/step - loss: 0.0865 -
acc: 0.9672 - val_loss: 0.1446 - val_acc: 0.9375
Epoch 97/100
162/163 [============================>.] - ETA: 0s - loss: 0.0858 - acc: 0
.9678Epoch 1/100
  1/163 [..............................] - ETA: 57s - loss: 0.1481 - acc:
```

```
0.9375
Epoch 00097: saving model to /content/data/model/weights.epoch_97.hdf5
163/163 [==============================] - 92s 566ms/step - loss: 0.0855 - acc: 0.9680 - val_loss: 0.1481 - val_acc: 0.9375
Epoch 98/100
162/163 [============================>.] - ETA: 0s - loss: 0.0926 - acc: 0.9701Epoch 1/100
  1/163 [..............................] - ETA: 1:01 - loss: 0.1280 - acc: 0.9375
Epoch 00098: saving model to /content/data/model/weights.epoch_98.hdf5
163/163 [==============================] - 92s 565ms/step - loss: 0.0934 - acc: 0.9697 - val_loss: 0.1280 - val_acc: 0.9375
Epoch 99/100
162/163 [============================>.] - ETA: 0s - loss: 0.0843 - acc: 0.9722Epoch 1/100
  1/163 [..............................] - ETA: 1:02 - loss: 0.1512 - acc: 0.8750
Epoch 00099: saving model to /content/data/model/weights.epoch_99.hdf5
163/163 [==============================] - 92s 566ms/step - loss: 0.0841 - acc: 0.9722 - val_loss: 0.1512 - val_acc: 0.8750
Epoch 100/100
162/163 [============================>.] - ETA: 0s - loss: 0.0831 - acc: 0.9730Epoch 1/100
  1/163 [..............................] - ETA: 59s - loss: 0.1511 - acc: 0.9375
Epoch 00100: saving model to /content/data/model/weights.epoch_100.hdf5
163/163 [==============================] - 92s 562ms/step - loss: 0.0832 - acc: 0.9728 - val_loss: 0.1511 - val_acc: 0.9375
```

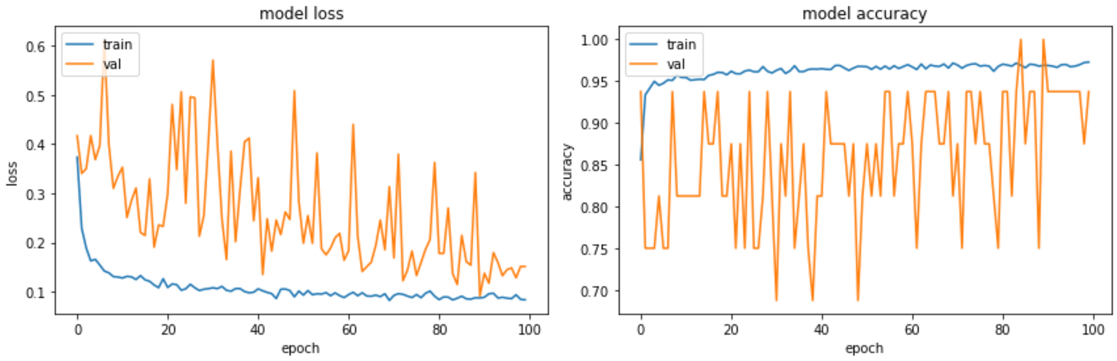
```python
import matplotlib.pyplot as plt
def plot_learning_curves(history):
    plt.figure(figsize=(12,4))

    plt.subplot(1,2,1)
    plt.plot(history.history['loss'])
    plt.plot(history.history['val_loss'])
    plt.title('model loss')
    plt.ylabel('loss')
    plt.xlabel('epoch')
    plt.legend(['train', 'val'], loc='upper left')

    plt.subplot(1,2,2)
    plt.plot(history.history['acc'])
    plt.plot(history.history['val_acc'])
    plt.title('model accuracy')
    plt.ylabel('accuracy')
    plt.xlabel('epoch')
    plt.legend(['train', 'val'], loc='upper left')

    plt.tight_layout()

plot_learning_curves(history)
```



png

```
idx = np.argmin(history.history['val_loss'])
model.load_weights("/content/data/model/weights.epoch_{:02d}.hdf5".format(
idx + 1))

print("Loading the best model")
print("epoch: {}, val_loss: {}, val_acc: {}".format(idx + 1, history.histo
ry['val_loss'][idx], history.history['val_acc'][idx]))
```

```
Loading the best model
epoch: 90, val_loss: 0.09109506011009216, val_acc: 1.0
```

```
test_loss, test_acc = model.evaluate_generator(generator=test_generator, v
erbose=1)
```

```
20/20 [==============================] - 8s 403ms/step - loss: 0.2567 - ac
c: 0.9183
```

```
from sklearn.metrics import accuracy_score, confusion_matrix

test_generator.reset()
test_preds = model.predict_generator(test_generator, verbose=1)
test_preds = np.argmax(test_preds,axis=1)

acc = accuracy_score(test_generator.classes, test_preds)*100
cm = confusion_matrix(test_generator.classes, test_preds)
tn, fp, fn, tp = cm.ravel()

print('CONFUSION MATRIX ------------------')
print(cm)
# plot_confusion_matrix(cm, target_names=['NORMAL', 'PNEUMONIA'], normaliz
e=False)


print('\nTEST METRICS ----------------------')
precision = tp/(tp+fp)*100
recall = tp/(tp+fn)*100
print('Accuracy: {}%'.format(acc))
print('Precision: {}%'.format(precision))
print('Recall: {}%'.format(recall))
print('F1-score: {}'.format(2*precision*recall/(precision+recall)))
```

```
print('\nTRAIN METRIC ----------------------')
print('Train acc: {}%'.format(np.round((history.history['acc'][-1])*100, 1
4)))
```

```
20/20 [==============================] - 8s 408ms/step
CONFUSION MATRIX ------------------
[[200  34]
 [ 17 373]]

TEST METRICS ----------------------
Accuracy: 91.82692307692307%
Precision: 91.64619164619164%
Recall: 95.64102564102565%
F1-score: 93.60100376411543

TRAIN METRIC ----------------------
Train acc: 97.27760553359985%
```

9.10 Appendix J: ResNet50V2

```
from __future__ import absolute_import, division, print_function, unicode_
literals
import tensorflow as tf

# Extract dataset
import os
import tarfile

import keras_preprocessing
from keras_preprocessing.image import ImageDataGenerator # Data preprocess
ing and augmentation

import sklearn
import numpy as np
```

The default version of TensorFlow in Colab will soon switch to TensorFlow 2.x. We recommend you upgrade now or ensure your notebook will continue to use TensorFlow 1.x via the %tensorflow_version 1.x magic: more info.

```
print(tf.__version__)
```

```
1.15.0
```

```
# Make folder for chest xray data
!mkdir /content/data/

# Make directory to save weights
!mkdir /content/data/model

# Make directory to logs for Tensorboard
!mkdir /content/data/graph

# Download dataset
!wget --no-check-certificate \
    https://s3.eu-central-1.amazonaws.com/public.unit8.co/data/chest_xray.
tar.gz \
    -O /content/data/chest_xray.tar.gz

tar = tarfile.open("data/chest_xray.tar.gz")
tar.extractall(path='./data/')
os.remove('data/chest_xray.tar.gz')
```

```
--2019-11-08 04:14:02--  https://s3.eu-central-1.amazonaws.com/public.unit
8.co/data/chest_xray.tar.gz
Resolving s3.eu-central-1.amazonaws.com (s3.eu-central-1.amazonaws.com)...
52.219.72.8
Connecting to s3.eu-central-1.amazonaws.com (s3.eu-central-1.amazonaws.com
)|52.219.72.8|:443... connected.
HTTP request sent, awaiting response... 200 OK
Length: 1225393795 (1.1G) [application/x-gzip]
Saving to: ‘/content/data/chest_xray.tar.gz’
```

```
/content/data/chest 100%[===================>]   1.14G  85.7MB/s    in 14s

2019-11-08 04:14:17 (83.8 MB/s) - '/content/data/chest_xray.tar.gz' saved
[1225393795/1225393795]
```

Change log: > training_datagen –> ImageDataGenerator

trainable layer –> All except base

20 layers VGG16 model - base, flat, dense

Optimizer = RMSprop(learning_rate = 0.0001)

loss = categorical_crosscentropy

callback = [checkpoints]

epochs = 100

no class weight balancing

```
TRAINING_DIR = "/content/data/chest_xray/train"
VALIDATION_DIR = "/content/data/chest_xray/val"
TEST_DIR = "/content/data/chest_xray/test"

training_datagen = ImageDataGenerator(
    preprocessing_function=tf.keras.applications.vgg16.preprocess_input,
    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,
    # vertical_flip=True
    fill_mode='nearest'
)

validation_datagen = ImageDataGenerator(
    rescale = 1./255
)

test_datagen = ImageDataGenerator(
    rescale = 1./255
)

# Create training data batch
# TODO: Try grayscaling the image to see what will happen
train_generator = training_datagen.flow_from_directory(
    TRAINING_DIR,
    target_size=(150,150),
    class_mode='categorical'
)

validation_generator = validation_datagen.flow_from_directory(
    VALIDATION_DIR,
    target_size=(150,150),
```

```
    class_mode='categorical'
)

test_generator = test_datagen.flow_from_directory(
    TEST_DIR,
    target_size=(150,150),
    class_mode='categorical',
    shuffle=False
)

train_shape = train_generator.image_shape

tf.keras.backend.clear_session() # Destroys the current TF graph and creat
es a new one.

base_model = tf.keras.applications.resnet_v2.ResNet50V2(weights='imagenet'
, include_top=False, input_shape=train_shape)

# Define the machine learning model
x = base_model.output
x = tf.keras.layers.Flatten()(x)
x = tf.keras.layers.Dense(2, 'softmax')(x)

model = tf.keras.Model(inputs=base_model.input, outputs=x)

# for layer in model.layers[0:20]:
#     layer.trainable = False

for layer in base_model.layers:
  layer.trainable = False

optimizer = tf.keras.optimizers.RMSprop(learning_rate=0.0001) # Lower lear
ning rate by x10

model.compile(loss='categorical_crossentropy',
              optimizer=optimizer,
              metrics=['accuracy'])

# Callbacks stuff
# Function to save the weights of the model after each epoch
checkpoint = tf.keras.callbacks.ModelCheckpoint(
    '/content/data/model/weights.epoch_{epoch:02d}.hdf5',
    monitor='val_accuracy',
    save_best_only=False,
    save_weights_only=False,
    mode='auto',
    verbose=1
)

# Function to stop training early if there's no improvement
early_stopping_monitor = tf.keras.callbacks.EarlyStopping(patience = 3, mo
nitor = "val_loss", mode="auto", verbose = 1)

lr_reduce = tf.keras.callbacks.ReduceLROnPlateau(monitor='val_loss', facto
```

```
r=0.3, patience=2, verbose=1, mode='max')

classweight = sklearn.utils.class_weight.compute_class_weight('balanced',
np.unique(train_generator.labels), train_generator.labels)
print(classweight)

batch_size = 32
epochs = 100

# Training process
history = model.fit_generator(
    generator=train_generator,
    # steps_per_epoch=train_generator.samples//batch_size,
    epochs=epochs,
    # callbacks=[early_stopping_monitor],
    callbacks=[checkpoint],
    # shuffle=True,
    validation_data=validation_generator,
    # validation_steps= validation_generator//batch_size, #no because it's
gonna be 0... if leave alone its len(generator) which is equal to 1.
    # class_weight=classweight,
    verbose = 1
)

# test_loss, test_acc = model.evaluate_generator(generator=test_generator,
verbose=1)

### Plot training
import matplotlib.pyplot as plt
def plot_learning_curves(history):
    plt.figure(figsize=(12,4))

    plt.subplot(1,2,1)
    plt.plot(history.history['loss'])
    plt.plot(history.history['val_loss'])
    plt.title('model loss')
    plt.ylabel('loss')
    plt.xlabel('epoch')
    plt.legend(['train', 'val'], loc='upper left')

    plt.subplot(1,2,2)
    plt.plot(history.history['acc'])
    plt.plot(history.history['val_acc'])
    plt.title('model accuracy')
    plt.ylabel('accuracy')
    plt.xlabel('epoch')
    plt.legend(['train', 'val'], loc='upper left')

    plt.tight_layout()

plot_learning_curves(history)

## Load best weight
idx = np.argmin(history.history['val_loss'])
```

```
model.load_weights("/content/data/model/weights.epoch_{:02d}.hdf5".format(
idx + 1))

print("Loading the best model")
print("epoch: {}, val_loss: {}, val_acc: {}".format(idx + 1, history.histo
ry['val_loss'][idx], history.history['val_acc'][idx]))

## Evaluate the model
test_loss, test_acc = model.evaluate_generator(generator=test_generator, v
erbose=1)

## Analytics
from sklearn.metrics import accuracy_score, confusion_matrix

test_generator.reset()
test_preds = model.predict_generator(test_generator, verbose=1)
test_preds = np.argmax(test_preds,axis=1)

acc = accuracy_score(test_generator.classes, test_preds)*100
cm = confusion_matrix(test_generator.classes, test_preds)
tn, fp, fn, tp = cm.ravel()

print('CONFUSION MATRIX ------------------')
print(cm)
# plot_confusion_matrix(cm, target_names=['NORMAL', 'PNEUMONIA'], normaliz
e=False)


print('\nTEST METRICS ----------------------')
precision = tp/(tp+fp)*100
recall = tp/(tp+fn)*100
print('Accuracy: {}%'.format(acc))
print('Precision: {}%'.format(precision))
print('Recall: {}%'.format(recall))
print('F1-score: {}'.format(2*precision*recall/(precision+recall)))

print('\nTRAIN METRIC ----------------------')
print('Train acc: {}%'.format(np.round((history.history['acc'][-1])*100, 1
4)))
```

```
Found 5216 images belonging to 2 classes.
Found 16 images belonging to 2 classes.
Found 624 images belonging to 2 classes.
WARNING:tensorflow:From /usr/local/lib/python3.6/dist-packages/tensorflow_
core/python/ops/resource_variable_ops.py:1630: calling BaseResourceVariabl
e.__init__ (from tensorflow.python.ops.resource_variable_ops) with constra
int is deprecated and will be removed in a future version.
Instructions for updating:
If using Keras pass *_constraint arguments to layers.
Downloading data from https://github.com/keras-team/keras-applications/rel
eases/download/resnet/resnet50v2_weights_tf_dim_ordering_tf_kernels_notop.
h5
94674944/94668760 [==============================] - 3s 0us/step
[1.9448173  0.67303226]
```

```
Epoch 1/100
162/163 [============================>.] - ETA: 0s - loss: 0.2824 - acc: 0
.8966Epoch 1/100
  1/163 [..............................] - ETA: 6:11 - loss: 0.8304 - acc:
0.8125
Epoch 00001: saving model to /content/data/model/weights.epoch_01.hdf5
163/163 [==============================] - 95s 581ms/step - loss: 0.2818 -
acc: 0.8967 - val_loss: 0.8304 - val_acc: 0.8125
Epoch 2/100
162/163 [============================>.] - ETA: 0s - loss: 0.1982 - acc: 0
.9356Epoch 1/100
  1/163 [..............................] - ETA: 50s - loss: 2.0862 - acc:
0.6250
Epoch 00002: saving model to /content/data/model/weights.epoch_02.hdf5
163/163 [==============================] - 77s 472ms/step - loss: 0.1973 -
acc: 0.9358 - val_loss: 2.0862 - val_acc: 0.6250
Epoch 3/100
162/163 [============================>.] - ETA: 0s - loss: 0.1548 - acc: 0
.9483Epoch 1/100
  1/163 [..............................] - ETA: 54s - loss: 0.9625 - acc:
0.7500
Epoch 00003: saving model to /content/data/model/weights.epoch_03.hdf5
163/163 [==============================] - 81s 495ms/step - loss: 0.1557 -
acc: 0.9479 - val_loss: 0.9625 - val_acc: 0.7500
Epoch 4/100
162/163 [============================>.] - ETA: 0s - loss: 0.1416 - acc: 0
.9502Epoch 1/100
  1/163 [..............................] - ETA: 50s - loss: 3.3152 - acc:
0.6250
Epoch 00004: saving model to /content/data/model/weights.epoch_04.hdf5
163/163 [==============================] - 81s 494ms/step - loss: 0.1425 -
acc: 0.9496 - val_loss: 3.3152 - val_acc: 0.6250
Epoch 5/100
162/163 [============================>.] - ETA: 0s - loss: 0.1407 - acc: 0
.9539Epoch 1/100
  1/163 [..............................] - ETA: 51s - loss: 4.5362 - acc:
0.5000
Epoch 00005: saving model to /content/data/model/weights.epoch_05.hdf5
163/163 [==============================] - 81s 496ms/step - loss: 0.1399 -
acc: 0.9542 - val_loss: 4.5362 - val_acc: 0.5000
Epoch 6/100
162/163 [============================>.] - ETA: 0s - loss: 0.1265 - acc: 0
.9551Epoch 1/100
  1/163 [..............................] - ETA: 50s - loss: 2.8676 - acc:
0.5625
Epoch 00006: saving model to /content/data/model/weights.epoch_06.hdf5
163/163 [==============================] - 80s 494ms/step - loss: 0.1259 -
acc: 0.9553 - val_loss: 2.8676 - val_acc: 0.5625
Epoch 7/100
162/163 [============================>.] - ETA: 0s - loss: 0.1267 - acc: 0
.9576Epoch 1/100
  1/163 [..............................] - ETA: 53s - loss: 2.9686 - acc:
0.6250
Epoch 00007: saving model to /content/data/model/weights.epoch_07.hdf5
```

```
163/163 [==============================] - 80s 491ms/step - loss: 0.1261 -
acc: 0.9578 - val_loss: 2.9686 - val_acc: 0.6250
Epoch 8/100
162/163 [============================>.] - ETA: 0s - loss: 0.1099 - acc: 0
.9657Epoch 1/100
  1/163 [..............................] - ETA: 50s - loss: 4.3251 - acc:
0.5625
Epoch 00008: saving model to /content/data/model/weights.epoch_08.hdf5
163/163 [==============================] - 80s 493ms/step - loss: 0.1104 -
acc: 0.9655 - val_loss: 4.3251 - val_acc: 0.5625
Epoch 9/100
162/163 [============================>.] - ETA: 0s - loss: 0.0994 - acc: 0
.9660Epoch 1/100
  1/163 [..............................] - ETA: 52s - loss: 5.9945 - acc:
0.5000
Epoch 00009: saving model to /content/data/model/weights.epoch_09.hdf5
163/163 [==============================] - 80s 489ms/step - loss: 0.0999 -
acc: 0.9655 - val_loss: 5.9945 - val_acc: 0.5000
Epoch 10/100
162/163 [============================>.] - ETA: 0s - loss: 0.1189 - acc: 0
.9618Epoch 1/100
  1/163 [..............................] - ETA: 50s - loss: 3.3174 - acc:
0.6250
Epoch 00010: saving model to /content/data/model/weights.epoch_10.hdf5
163/163 [==============================] - 80s 491ms/step - loss: 0.1182 -
acc: 0.9620 - val_loss: 3.3174 - val_acc: 0.6250
Epoch 11/100
162/163 [============================>.] - ETA: 0s - loss: 0.1122 - acc: 0
.9651Epoch 1/100
  1/163 [..............................] - ETA: 50s - loss: 6.8161 - acc:
0.5000
Epoch 00011: saving model to /content/data/model/weights.epoch_11.hdf5
163/163 [==============================] - 80s 491ms/step - loss: 0.1119 -
acc: 0.9651 - val_loss: 6.8161 - val_acc: 0.5000
Epoch 12/100
162/163 [============================>.] - ETA: 0s - loss: 0.1041 - acc: 0
.9662Epoch 1/100
  1/163 [..............................] - ETA: 53s - loss: 6.4790 - acc:
0.5000
Epoch 00012: saving model to /content/data/model/weights.epoch_12.hdf5
163/163 [==============================] - 80s 488ms/step - loss: 0.1036 -
acc: 0.9663 - val_loss: 6.4790 - val_acc: 0.5000
Epoch 13/100
162/163 [============================>.] - ETA: 0s - loss: 0.0991 - acc: 0
.9678Epoch 1/100
  1/163 [..............................] - ETA: 50s - loss: 6.4378 - acc:
0.5000
Epoch 00013: saving model to /content/data/model/weights.epoch_13.hdf5
163/163 [==============================] - 83s 507ms/step - loss: 0.1002 -
acc: 0.9674 - val_loss: 6.4378 - val_acc: 0.5000
Epoch 14/100
162/163 [============================>.] - ETA: 0s - loss: 0.0935 - acc: 0
.9670Epoch 1/100
  1/163 [..............................] - ETA: 55s - loss: 6.1984 - acc:
```

```
0.5000
Epoch 00014: saving model to /content/data/model/weights.epoch_14.hdf5
163/163 [==============================] - 83s 511ms/step - loss: 0.0941 -
acc: 0.9668 - val_loss: 6.1984 - val_acc: 0.5000
Epoch 15/100
162/163 [============================>.] - ETA: 0s - loss: 0.0984 - acc: 0
.9686Epoch 1/100
  1/163 [..............................] - ETA: 52s - loss: 6.0110 - acc:
0.5000
Epoch 00015: saving model to /content/data/model/weights.epoch_15.hdf5
163/163 [==============================] - 85s 520ms/step - loss: 0.0978 -
acc: 0.9688 - val_loss: 6.0110 - val_acc: 0.5000
Epoch 16/100
162/163 [============================>.] - ETA: 0s - loss: 0.1009 - acc: 0
.9699Epoch 1/100
  1/163 [..............................] - ETA: 56s - loss: 6.4342 - acc:
0.5000
Epoch 00016: saving model to /content/data/model/weights.epoch_16.hdf5
163/163 [==============================] - 85s 521ms/step - loss: 0.1006 -
acc: 0.9699 - val_loss: 6.4342 - val_acc: 0.5000
Epoch 17/100
162/163 [============================>.] - ETA: 0s - loss: 0.0859 - acc: 0
.9716Epoch 1/100
  1/163 [..............................] - ETA: 55s - loss: 6.4695 - acc:
0.5000
Epoch 00017: saving model to /content/data/model/weights.epoch_17.hdf5
163/163 [==============================] - 84s 516ms/step - loss: 0.0856 -
acc: 0.9716 - val_loss: 6.4695 - val_acc: 0.5000
Epoch 18/100
162/163 [============================>.] - ETA: 0s - loss: 0.0976 - acc: 0
.9693Epoch 1/100
  1/163 [..............................] - ETA: 52s - loss: 5.3972 - acc:
0.5625
Epoch 00018: saving model to /content/data/model/weights.epoch_18.hdf5
163/163 [==============================] - 84s 515ms/step - loss: 0.0971 -
acc: 0.9695 - val_loss: 5.3972 - val_acc: 0.5625
Epoch 19/100
162/163 [============================>.] - ETA: 0s - loss: 0.0888 - acc: 0
.9726Epoch 1/100
  1/163 [..............................] - ETA: 54s - loss: 4.0055 - acc:
0.5625
Epoch 00019: saving model to /content/data/model/weights.epoch_19.hdf5
163/163 [==============================] - 84s 517ms/step - loss: 0.0895 -
acc: 0.9722 - val_loss: 4.0055 - val_acc: 0.5625
Epoch 20/100
162/163 [============================>.] - ETA: 0s - loss: 0.0988 - acc: 0
.9713Epoch 1/100
  1/163 [..............................] - ETA: 52s - loss: 5.8819 - acc:
0.5625
Epoch 00020: saving model to /content/data/model/weights.epoch_20.hdf5
163/163 [==============================] - 85s 519ms/step - loss: 0.0986 -
acc: 0.9712 - val_loss: 5.8819 - val_acc: 0.5625
Epoch 21/100
162/163 [============================>.] - ETA: 0s - loss: 0.1007 - acc: 0
```

```
.9705Epoch 1/100
  1/163 [..............................] - ETA: 53s - loss: 6.4408 - acc:
0.5625
Epoch 00021: saving model to /content/data/model/weights.epoch_21.hdf5
163/163 [==============================] - 85s 519ms/step - loss: 0.1003 -
acc: 0.9707 - val_loss: 6.4408 - val_acc: 0.5625
Epoch 22/100
162/163 [============================>.] - ETA: 0s - loss: 0.0846 - acc: 0
.9732Epoch 1/100
  1/163 [..............................] - ETA: 51s - loss: 6.7749 - acc:
0.5000
Epoch 00022: saving model to /content/data/model/weights.epoch_22.hdf5
163/163 [==============================] - 85s 519ms/step - loss: 0.0847 -
acc: 0.9732 - val_loss: 6.7749 - val_acc: 0.5000
Epoch 23/100
162/163 [============================>.] - ETA: 0s - loss: 0.1020 - acc: 0
.9707Epoch 1/100
  1/163 [..............................] - ETA: 53s - loss: 7.9478 - acc:
0.5000
Epoch 00023: saving model to /content/data/model/weights.epoch_23.hdf5
163/163 [==============================] - 85s 518ms/step - loss: 0.1026 -
acc: 0.9703 - val_loss: 7.9478 - val_acc: 0.5000
Epoch 24/100
162/163 [============================>.] - ETA: 0s - loss: 0.0776 - acc: 0
.9740Epoch 1/100
  1/163 [..............................] - ETA: 56s - loss: 8.0591 - acc:
0.5000
Epoch 00024: saving model to /content/data/model/weights.epoch_24.hdf5
163/163 [==============================] - 85s 523ms/step - loss: 0.0772 -
acc: 0.9741 - val_loss: 8.0591 - val_acc: 0.5000
Epoch 25/100
162/163 [============================>.] - ETA: 0s - loss: 0.0890 - acc: 0
.9707Epoch 1/100
  1/163 [..............................] - ETA: 52s - loss: 6.3816 - acc:
0.5000
Epoch 00025: saving model to /content/data/model/weights.epoch_25.hdf5
163/163 [==============================] - 85s 523ms/step - loss: 0.0887 -
acc: 0.9707 - val_loss: 6.3816 - val_acc: 0.5000
Epoch 26/100
162/163 [============================>.] - ETA: 0s - loss: 0.0863 - acc: 0
.9740Epoch 1/100
  1/163 [..............................] - ETA: 51s - loss: 6.5415 - acc:
0.5000
Epoch 00026: saving model to /content/data/model/weights.epoch_26.hdf5
163/163 [==============================] - 86s 526ms/step - loss: 0.0862 -
acc: 0.9739 - val_loss: 6.5415 - val_acc: 0.5000
Epoch 27/100
162/163 [============================>.] - ETA: 0s - loss: 0.0889 - acc: 0
.9726Epoch 1/100
  1/163 [..............................] - ETA: 53s - loss: 8.1368 - acc:
0.5000
Epoch 00027: saving model to /content/data/model/weights.epoch_27.hdf5
163/163 [==============================] - 86s 525ms/step - loss: 0.0883 -
acc: 0.9728 - val_loss: 8.1368 - val_acc: 0.5000
```

```
Epoch 28/100
162/163 [============================>.] - ETA: 0s - loss: 0.1028 - acc: 0
.9720Epoch 1/100
  1/163 [..............................] - ETA: 53s - loss: 8.3632 - acc:
0.5000
Epoch 00028: saving model to /content/data/model/weights.epoch_28.hdf5
163/163 [==============================] - 85s 523ms/step - loss: 0.1026 -
acc: 0.9720 - val_loss: 8.3632 - val_acc: 0.5000
Epoch 29/100
162/163 [============================>.] - ETA: 0s - loss: 0.0850 - acc: 0
.9724Epoch 1/100
  1/163 [..............................] - ETA: 52s - loss: 8.6129 - acc:
0.5000
Epoch 00029: saving model to /content/data/model/weights.epoch_29.hdf5
163/163 [==============================] - 86s 525ms/step - loss: 0.0849 -
acc: 0.9724 - val_loss: 8.6129 - val_acc: 0.5000
Epoch 30/100
162/163 [============================>.] - ETA: 0s - loss: 0.1020 - acc: 0
.9738Epoch 1/100
  1/163 [..............................] - ETA: 52s - loss: 10.9667 - acc:
0.5000
Epoch 00030: saving model to /content/data/model/weights.epoch_30.hdf5
163/163 [==============================] - 86s 526ms/step - loss: 0.1014 -
acc: 0.9739 - val_loss: 10.9667 - val_acc: 0.5000
Epoch 31/100
162/163 [============================>.] - ETA: 0s - loss: 0.0753 - acc: 0
.9761Epoch 1/100
  1/163 [..............................] - ETA: 53s - loss: 7.7622 - acc:
0.5000
Epoch 00031: saving model to /content/data/model/weights.epoch_31.hdf5
163/163 [==============================] - 85s 524ms/step - loss: 0.0752 -
acc: 0.9760 - val_loss: 7.7622 - val_acc: 0.5000
Epoch 32/100
162/163 [============================>.] - ETA: 0s - loss: 0.0852 - acc: 0
.9745Epoch 1/100
  1/163 [..............................] - ETA: 51s - loss: 6.6926 - acc:
0.5000
Epoch 00032: saving model to /content/data/model/weights.epoch_32.hdf5
163/163 [==============================] - 85s 521ms/step - loss: 0.0847 -
acc: 0.9747 - val_loss: 6.6926 - val_acc: 0.5000
Epoch 33/100
162/163 [============================>.] - ETA: 0s - loss: 0.0782 - acc: 0
.9769Epoch 1/100
  1/163 [..............................] - ETA: 53s - loss: 4.1305 - acc:
0.6875
Epoch 00033: saving model to /content/data/model/weights.epoch_33.hdf5
163/163 [==============================] - 85s 524ms/step - loss: 0.0778 -
acc: 0.9770 - val_loss: 4.1305 - val_acc: 0.6875
Epoch 34/100
162/163 [============================>.] - ETA: 0s - loss: 0.0758 - acc: 0
.9774Epoch 1/100
  1/163 [..............................] - ETA: 51s - loss: 6.4277 - acc:
0.5000
Epoch 00034: saving model to /content/data/model/weights.epoch_34.hdf5
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163/163 [==============================] - 85s 523ms/step - loss: 0.0758 -
acc: 0.9772 - val_loss: 6.4277 - val_acc: 0.5000
Epoch 35/100
162/163 [============================>.] - ETA: 0s - loss: 0.0752 - acc: 0
.9782Epoch 1/100
  1/163 [..............................] - ETA: 55s - loss: 8.0318 - acc:
0.5000
Epoch 00035: saving model to /content/data/model/weights.epoch_35.hdf5
163/163 [==============================] - 85s 524ms/step - loss: 0.0749 -
acc: 0.9781 - val_loss: 8.0318 - val_acc: 0.5000
Epoch 36/100
162/163 [============================>.] - ETA: 0s - loss: 0.0716 - acc: 0
.9767Epoch 1/100
  1/163 [..............................] - ETA: 54s - loss: 7.8507 - acc:
0.5000
Epoch 00036: saving model to /content/data/model/weights.epoch_36.hdf5
163/163 [==============================] - 85s 522ms/step - loss: 0.0712 -
acc: 0.9768 - val_loss: 7.8507 - val_acc: 0.5000
Epoch 37/100
162/163 [============================>.] - ETA: 0s - loss: 0.0738 - acc: 0
.9776Epoch 1/100
  1/163 [..............................] - ETA: 53s - loss: 7.4273 - acc:
0.5625
Epoch 00037: saving model to /content/data/model/weights.epoch_37.hdf5
163/163 [==============================] - 86s 526ms/step - loss: 0.0737 -
acc: 0.9776 - val_loss: 7.4273 - val_acc: 0.5625
Epoch 38/100
162/163 [============================>.] - ETA: 0s - loss: 0.0796 - acc: 0
.9730Epoch 1/100
  1/163 [..............................] - ETA: 55s - loss: 6.2294 - acc:
0.5625
Epoch 00038: saving model to /content/data/model/weights.epoch_38.hdf5
163/163 [==============================] - 86s 528ms/step - loss: 0.0796 -
acc: 0.9730 - val_loss: 6.2294 - val_acc: 0.5625
Epoch 39/100
162/163 [============================>.] - ETA: 0s - loss: 0.0788 - acc: 0
.9757Epoch 1/100
  1/163 [..............................] - ETA: 55s - loss: 6.5632 - acc:
0.5000
Epoch 00039: saving model to /content/data/model/weights.epoch_39.hdf5
163/163 [==============================] - 85s 523ms/step - loss: 0.0784 -
acc: 0.9758 - val_loss: 6.5632 - val_acc: 0.5000
Epoch 40/100
162/163 [============================>.] - ETA: 0s - loss: 0.0843 - acc: 0
.9761Epoch 1/100
  1/163 [..............................] - ETA: 55s - loss: 6.6225 - acc:
0.5625
Epoch 00040: saving model to /content/data/model/weights.epoch_40.hdf5
163/163 [==============================] - 86s 525ms/step - loss: 0.0848 -
acc: 0.9760 - val_loss: 6.6225 - val_acc: 0.5625
Epoch 41/100
162/163 [============================>.] - ETA: 0s - loss: 0.0926 - acc: 0
.9711Epoch 1/100
  1/163 [..............................] - ETA: 53s - loss: 10.5288 - acc:
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0.5000
Epoch 00041: saving model to /content/data/model/weights.epoch_41.hdf5
163/163 [==============================] - 86s 526ms/step - loss: 0.0921 -
acc: 0.9712 - val_loss: 10.5288 - val_acc: 0.5000
Epoch 42/100
162/163 [============================>.] - ETA: 0s - loss: 0.0812 - acc: 0
.9759Epoch 1/100
  1/163 [..............................] - ETA: 57s - loss: 7.3827 - acc:
0.5000
Epoch 00042: saving model to /content/data/model/weights.epoch_42.hdf5
163/163 [==============================] - 86s 530ms/step - loss: 0.0807 -
acc: 0.9760 - val_loss: 7.3827 - val_acc: 0.5000
Epoch 43/100
162/163 [============================>.] - ETA: 0s - loss: 0.0590 - acc: 0
.9792Epoch 1/100
  1/163 [..............................] - ETA: 53s - loss: 10.0128 - acc:
0.5000
Epoch 00043: saving model to /content/data/model/weights.epoch_43.hdf5
163/163 [==============================] - 86s 527ms/step - loss: 0.0587 -
acc: 0.9793 - val_loss: 10.0128 - val_acc: 0.5000
Epoch 44/100
162/163 [============================>.] - ETA: 0s - loss: 0.0906 - acc: 0
.9755Epoch 1/100
  1/163 [..............................] - ETA: 54s - loss: 10.3990 - acc:
0.5000
Epoch 00044: saving model to /content/data/model/weights.epoch_44.hdf5
163/163 [==============================] - 86s 525ms/step - loss: 0.0906 -
acc: 0.9755 - val_loss: 10.3990 - val_acc: 0.5000
Epoch 45/100
162/163 [============================>.] - ETA: 0s - loss: 0.0788 - acc: 0
.9769Epoch 1/100
  1/163 [..............................] - ETA: 53s - loss: 11.6837 - acc:
0.5000
Epoch 00045: saving model to /content/data/model/weights.epoch_45.hdf5
163/163 [==============================] - 86s 526ms/step - loss: 0.0787 -
acc: 0.9768 - val_loss: 11.6837 - val_acc: 0.5000
Epoch 46/100
162/163 [============================>.] - ETA: 0s - loss: 0.0935 - acc: 0
.9738Epoch 1/100
  1/163 [..............................] - ETA: 54s - loss: 9.3021 - acc:
0.5000
Epoch 00046: saving model to /content/data/model/weights.epoch_46.hdf5
163/163 [==============================] - 86s 528ms/step - loss: 0.0930 -
acc: 0.9739 - val_loss: 9.3021 - val_acc: 0.5000
Epoch 47/100
162/163 [============================>.] - ETA: 0s - loss: 0.0700 - acc: 0
.9799Epoch 1/100
  1/163 [..............................] - ETA: 55s - loss: 8.2738 - acc:
0.5000
Epoch 00047: saving model to /content/data/model/weights.epoch_47.hdf5
163/163 [==============================] - 86s 527ms/step - loss: 0.0696 -
acc: 0.9801 - val_loss: 8.2738 - val_acc: 0.5000
Epoch 48/100
162/163 [============================>.] - ETA: 0s - loss: 0.0755 - acc: 0
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.9778Epoch 1/100
  1/163 [..............................] - ETA: 53s - loss: 9.4213 - acc: 
0.5000
Epoch 00048: saving model to /content/data/model/weights.epoch_48.hdf5
163/163 [==============================] - 86s 526ms/step - loss: 0.0751 - 
acc: 0.9780 - val_loss: 9.4213 - val_acc: 0.5000
Epoch 49/100
162/163 [============================>.] - ETA: 0s - loss: 0.0786 - acc: 0
.9767Epoch 1/100
  1/163 [..............................] - ETA: 54s - loss: 7.9777 - acc: 
0.5000
Epoch 00049: saving model to /content/data/model/weights.epoch_49.hdf5
163/163 [==============================] - 86s 526ms/step - loss: 0.0783 - 
acc: 0.9766 - val_loss: 7.9777 - val_acc: 0.5000
Epoch 50/100
162/163 [============================>.] - ETA: 0s - loss: 0.0655 - acc: 0
.9772Epoch 1/100
  1/163 [..............................] - ETA: 51s - loss: 6.6981 - acc: 
0.5000
Epoch 00050: saving model to /content/data/model/weights.epoch_50.hdf5
163/163 [==============================] - 86s 528ms/step - loss: 0.0668 - 
acc: 0.9772 - val_loss: 6.6981 - val_acc: 0.5000
Epoch 51/100
162/163 [============================>.] - ETA: 0s - loss: 0.0696 - acc: 0
.9790Epoch 1/100
  1/163 [..............................] - ETA: 52s - loss: 7.3452 - acc: 
0.5000
Epoch 00051: saving model to /content/data/model/weights.epoch_51.hdf5
163/163 [==============================] - 86s 528ms/step - loss: 0.0692 - 
acc: 0.9791 - val_loss: 7.3452 - val_acc: 0.5000
Epoch 52/100
162/163 [============================>.] - ETA: 0s - loss: 0.0764 - acc: 0
.9780Epoch 1/100
  1/163 [..............................] - ETA: 51s - loss: 7.5369 - acc: 
0.5000
Epoch 00052: saving model to /content/data/model/weights.epoch_52.hdf5
163/163 [==============================] - 86s 526ms/step - loss: 0.0763 - 
acc: 0.9780 - val_loss: 7.5369 - val_acc: 0.5000
Epoch 53/100
162/163 [============================>.] - ETA: 0s - loss: 0.0817 - acc: 0
.9774Epoch 1/100
  1/163 [..............................] - ETA: 54s - loss: 5.7383 - acc: 
0.5000
Epoch 00053: saving model to /content/data/model/weights.epoch_53.hdf5
163/163 [==============================] - 86s 528ms/step - loss: 0.0818 - 
acc: 0.9772 - val_loss: 5.7383 - val_acc: 0.5000
Epoch 54/100
162/163 [============================>.] - ETA: 0s - loss: 0.0707 - acc: 0
.9815Epoch 1/100
  1/163 [..............................] - ETA: 54s - loss: 6.5155 - acc: 
0.5000
Epoch 00054: saving model to /content/data/model/weights.epoch_54.hdf5
163/163 [==============================] - 86s 527ms/step - loss: 0.0708 - 
acc: 0.9812 - val_loss: 6.5155 - val_acc: 0.5000
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Epoch 55/100
162/163 [============================>.] - ETA: 0s - loss: 0.0776 - acc: 0
.9782Epoch 1/100
  1/163 [..............................] - ETA: 56s - loss: 7.7717 - acc:
0.5000
Epoch 00055: saving model to /content/data/model/weights.epoch_55.hdf5
163/163 [==============================] - 86s 526ms/step - loss: 0.0786 -
acc: 0.9780 - val_loss: 7.7717 - val_acc: 0.5000
Epoch 56/100
162/163 [============================>.] - ETA: 0s - loss: 0.0676 - acc: 0
.9807Epoch 1/100
  1/163 [..............................] - ETA: 53s - loss: 6.3639 - acc:
0.5000
Epoch 00056: saving model to /content/data/model/weights.epoch_56.hdf5
163/163 [==============================] - 86s 527ms/step - loss: 0.0675 -
acc: 0.9806 - val_loss: 6.3639 - val_acc: 0.5000
Epoch 57/100
162/163 [============================>.] - ETA: 0s - loss: 0.0586 - acc: 0
.9834Epoch 1/100
  1/163 [..............................] - ETA: 54s - loss: 8.9210 - acc:
0.5000
Epoch 00057: saving model to /content/data/model/weights.epoch_57.hdf5
163/163 [==============================] - 86s 529ms/step - loss: 0.0586 -
acc: 0.9833 - val_loss: 8.9210 - val_acc: 0.5000
Epoch 58/100
162/163 [============================>.] - ETA: 0s - loss: 0.0818 - acc: 0
.9778Epoch 1/100
  1/163 [..............................] - ETA: 51s - loss: 5.4594 - acc:
0.6250
Epoch 00058: saving model to /content/data/model/weights.epoch_58.hdf5
163/163 [==============================] - 86s 527ms/step - loss: 0.0814 -
acc: 0.9778 - val_loss: 5.4594 - val_acc: 0.6250
Epoch 59/100
162/163 [============================>.] - ETA: 0s - loss: 0.0711 - acc: 0
.9788Epoch 1/100
  1/163 [..............................] - ETA: 53s - loss: 7.3799 - acc:
0.5000
Epoch 00059: saving model to /content/data/model/weights.epoch_59.hdf5
163/163 [==============================] - 86s 528ms/step - loss: 0.0713 -
acc: 0.9787 - val_loss: 7.3799 - val_acc: 0.5000
Epoch 60/100
162/163 [============================>.] - ETA: 0s - loss: 0.0739 - acc: 0
.9784Epoch 1/100
  1/163 [..............................] - ETA: 55s - loss: 5.6847 - acc:
0.5625
Epoch 00060: saving model to /content/data/model/weights.epoch_60.hdf5
163/163 [==============================] - 86s 530ms/step - loss: 0.0735 -
acc: 0.9785 - val_loss: 5.6847 - val_acc: 0.5625
Epoch 61/100
162/163 [============================>.] - ETA: 0s - loss: 0.0718 - acc: 0
.9776Epoch 1/100
  1/163 [..............................] - ETA: 52s - loss: 6.9876 - acc:
0.5000
Epoch 00061: saving model to /content/data/model/weights.epoch_61.hdf5
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163/163 [==============================] - 86s 530ms/step - loss: 0.0716 -
acc: 0.9776 - val_loss: 6.9876 - val_acc: 0.5000
Epoch 62/100
162/163 [============================>.] - ETA: 0s - loss: 0.0822 - acc: 0
.9755Epoch 1/100
  1/163 [..............................] - ETA: 52s - loss: 5.7479 - acc:
0.5625
Epoch 00062: saving model to /content/data/model/weights.epoch_62.hdf5
163/163 [==============================] - 86s 529ms/step - loss: 0.0818 -
acc: 0.9757 - val_loss: 5.7479 - val_acc: 0.5625
Epoch 63/100
162/163 [============================>.] - ETA: 0s - loss: 0.0706 - acc: 0
.9782Epoch 1/100
  1/163 [..............................] - ETA: 52s - loss: 9.4446 - acc:
0.5000
Epoch 00063: saving model to /content/data/model/weights.epoch_63.hdf5
163/163 [==============================] - 86s 528ms/step - loss: 0.0704 -
acc: 0.9781 - val_loss: 9.4446 - val_acc: 0.5000
Epoch 64/100
162/163 [============================>.] - ETA: 0s - loss: 0.0735 - acc: 0
.9794Epoch 1/100
  1/163 [..............................] - ETA: 56s - loss: 8.7786 - acc:
0.5000
Epoch 00064: saving model to /content/data/model/weights.epoch_64.hdf5
163/163 [==============================] - 86s 528ms/step - loss: 0.0731 -
acc: 0.9795 - val_loss: 8.7786 - val_acc: 0.5000
Epoch 65/100
162/163 [============================>.] - ETA: 0s - loss: 0.0723 - acc: 0
.9780Epoch 1/100
  1/163 [..............................] - ETA: 55s - loss: 9.3511 - acc:
0.5000
Epoch 00065: saving model to /content/data/model/weights.epoch_65.hdf5
163/163 [==============================] - 86s 527ms/step - loss: 0.0719 -
acc: 0.9781 - val_loss: 9.3511 - val_acc: 0.5000
Epoch 66/100
162/163 [============================>.] - ETA: 0s - loss: 0.0813 - acc: 0
.9780Epoch 1/100
  1/163 [..............................] - ETA: 55s - loss: 9.4141 - acc:
0.5000
Epoch 00066: saving model to /content/data/model/weights.epoch_66.hdf5
163/163 [==============================] - 86s 525ms/step - loss: 0.0808 -
acc: 0.9781 - val_loss: 9.4141 - val_acc: 0.5000
Epoch 67/100
162/163 [============================>.] - ETA: 0s - loss: 0.0584 - acc: 0
.9809Epoch 1/100
  1/163 [..............................] - ETA: 53s - loss: 9.0598 - acc:
0.5000
Epoch 00067: saving model to /content/data/model/weights.epoch_67.hdf5
163/163 [==============================] - 86s 529ms/step - loss: 0.0593 -
acc: 0.9806 - val_loss: 9.0598 - val_acc: 0.5000
Epoch 68/100
162/163 [============================>.] - ETA: 0s - loss: 0.0586 - acc: 0
.9838Epoch 1/100
  1/163 [..............................] - ETA: 49s - loss: 9.7076 - acc:
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0.5000
Epoch 00068: saving model to /content/data/model/weights.epoch_68.hdf5
163/163 [==============================] - 86s 526ms/step - loss: 0.0588 -
acc: 0.9837 - val_loss: 9.7076 - val_acc: 0.5000
Epoch 69/100
162/163 [============================>.] - ETA: 0s - loss: 0.0726 - acc: 0
.9778Epoch 1/100
  1/163 [..............................] - ETA: 54s - loss: 10.0596 - acc:
0.5000
Epoch 00069: saving model to /content/data/model/weights.epoch_69.hdf5
163/163 [==============================] - 85s 523ms/step - loss: 0.0723 -
acc: 0.9780 - val_loss: 10.0596 - val_acc: 0.5000
Epoch 70/100
162/163 [============================>.] - ETA: 0s - loss: 0.0686 - acc: 0
.9807Epoch 1/100
  1/163 [..............................] - ETA: 54s - loss: 7.9896 - acc:
0.5000
Epoch 00070: saving model to /content/data/model/weights.epoch_70.hdf5
163/163 [==============================] - 85s 524ms/step - loss: 0.0689 -
acc: 0.9804 - val_loss: 7.9896 - val_acc: 0.5000
Epoch 71/100
162/163 [============================>.] - ETA: 0s - loss: 0.0736 - acc: 0
.9774Epoch 1/100
  1/163 [..............................] - ETA: 53s - loss: 8.1873 - acc:
0.5000
Epoch 00071: saving model to /content/data/model/weights.epoch_71.hdf5
163/163 [==============================] - 86s 528ms/step - loss: 0.0755 -
acc: 0.9772 - val_loss: 8.1873 - val_acc: 0.5000
Epoch 72/100
162/163 [============================>.] - ETA: 0s - loss: 0.0751 - acc: 0
.9794Epoch 1/100
  1/163 [..............................] - ETA: 53s - loss: 10.4079 - acc:
0.5000
Epoch 00072: saving model to /content/data/model/weights.epoch_72.hdf5
163/163 [==============================] - 85s 521ms/step - loss: 0.0746 -
acc: 0.9795 - val_loss: 10.4079 - val_acc: 0.5000
Epoch 73/100
162/163 [============================>.] - ETA: 0s - loss: 0.0746 - acc: 0
.9797Epoch 1/100
  1/163 [..............................] - ETA: 55s - loss: 8.7054 - acc:
0.5625
Epoch 00073: saving model to /content/data/model/weights.epoch_73.hdf5
163/163 [==============================] - 85s 522ms/step - loss: 0.0743 -
acc: 0.9797 - val_loss: 8.7054 - val_acc: 0.5625
Epoch 74/100
162/163 [============================>.] - ETA: 0s - loss: 0.0640 - acc: 0
.9796Epoch 1/100
  1/163 [..............................] - ETA: 54s - loss: 9.3623 - acc:
0.5000
Epoch 00074: saving model to /content/data/model/weights.epoch_74.hdf5
163/163 [==============================] - 85s 522ms/step - loss: 0.0636 -
acc: 0.9797 - val_loss: 9.3623 - val_acc: 0.5000
Epoch 75/100
162/163 [============================>.] - ETA: 0s - loss: 0.0666 - acc: 0
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.9826Epoch 1/100
  1/163 [..............................] - ETA: 52s - loss: 7.5627 - acc:
0.5625
Epoch 00075: saving model to /content/data/model/weights.epoch_75.hdf5
163/163 [==============================] - 85s 521ms/step - loss: 0.0663 -
acc: 0.9827 - val_loss: 7.5627 - val_acc: 0.5625
Epoch 76/100
162/163 [============================>.] - ETA: 0s - loss: 0.0741 - acc: 0
.9778Epoch 1/100
  1/163 [..............................] - ETA: 50s - loss: 8.9220 - acc:
0.5000
Epoch 00076: saving model to /content/data/model/weights.epoch_76.hdf5
163/163 [==============================] - 85s 520ms/step - loss: 0.0737 -
acc: 0.9780 - val_loss: 8.9220 - val_acc: 0.5000
Epoch 77/100
162/163 [============================>.] - ETA: 0s - loss: 0.0706 - acc: 0
.9786Epoch 1/100
  1/163 [..............................] - ETA: 52s - loss: 4.8831 - acc:
0.6250
Epoch 00077: saving model to /content/data/model/weights.epoch_77.hdf5
163/163 [==============================] - 84s 518ms/step - loss: 0.0709 -
acc: 0.9785 - val_loss: 4.8831 - val_acc: 0.6250
Epoch 78/100
162/163 [============================>.] - ETA: 0s - loss: 0.0722 - acc: 0
.9799Epoch 1/100
  1/163 [..............................] - ETA: 56s - loss: 5.9518 - acc:
0.5625
Epoch 00078: saving model to /content/data/model/weights.epoch_78.hdf5
163/163 [==============================] - 85s 522ms/step - loss: 0.0731 -
acc: 0.9799 - val_loss: 5.9518 - val_acc: 0.5625
Epoch 79/100
162/163 [============================>.] - ETA: 0s - loss: 0.0661 - acc: 0
.9799Epoch 1/100
  1/163 [..............................] - ETA: 51s - loss: 6.6153 - acc:
0.5625
Epoch 00079: saving model to /content/data/model/weights.epoch_79.hdf5
163/163 [==============================] - 85s 520ms/step - loss: 0.0671 -
acc: 0.9797 - val_loss: 6.6153 - val_acc: 0.5625
Epoch 80/100
162/163 [============================>.] - ETA: 0s - loss: 0.0534 - acc: 0
.9834Epoch 1/100
  1/163 [..............................] - ETA: 51s - loss: 8.5519 - acc:
0.5000
Epoch 00080: saving model to /content/data/model/weights.epoch_80.hdf5
163/163 [==============================] - 84s 517ms/step - loss: 0.0532 -
acc: 0.9835 - val_loss: 8.5519 - val_acc: 0.5000
Epoch 81/100
162/163 [============================>.] - ETA: 0s - loss: 0.0729 - acc: 0
.9792Epoch 1/100
  1/163 [..............................] - ETA: 52s - loss: 6.9769 - acc:
0.5625
Epoch 00081: saving model to /content/data/model/weights.epoch_81.hdf5
163/163 [==============================] - 84s 517ms/step - loss: 0.0724 -
acc: 0.9793 - val_loss: 6.9769 - val_acc: 0.5625
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Epoch 82/100
162/163 [============================>.] - ETA: 0s - loss: 0.0646 - acc: 0
.9797Epoch 1/100
  1/163 [..............................] - ETA: 53s - loss: 7.0855 - acc:
0.5000
Epoch 00082: saving model to /content/data/model/weights.epoch_82.hdf5
163/163 [==============================] - 85s 522ms/step - loss: 0.0652 -
acc: 0.9795 - val_loss: 7.0855 - val_acc: 0.5000
Epoch 83/100
162/163 [============================>.] - ETA: 0s - loss: 0.0713 - acc: 0
.9813Epoch 1/100
  1/163 [..............................] - ETA: 54s - loss: 4.9015 - acc:
0.6250
Epoch 00083: saving model to /content/data/model/weights.epoch_83.hdf5
163/163 [==============================] - 86s 529ms/step - loss: 0.0728 -
acc: 0.9812 - val_loss: 4.9015 - val_acc: 0.6250
Epoch 84/100
162/163 [============================>.] - ETA: 0s - loss: 0.0585 - acc: 0
.9832Epoch 1/100
  1/163 [..............................] - ETA: 52s - loss: 6.8088 - acc:
0.5000
Epoch 00084: saving model to /content/data/model/weights.epoch_84.hdf5
163/163 [==============================] - 86s 528ms/step - loss: 0.0583 -
acc: 0.9831 - val_loss: 6.8088 - val_acc: 0.5000
Epoch 85/100
162/163 [============================>.] - ETA: 0s - loss: 0.0718 - acc: 0
.9794Epoch 1/100
  1/163 [..............................] - ETA: 55s - loss: 7.9591 - acc:
0.5000
Epoch 00085: saving model to /content/data/model/weights.epoch_85.hdf5
163/163 [==============================] - 88s 539ms/step - loss: 0.0715 -
acc: 0.9795 - val_loss: 7.9591 - val_acc: 0.5000
Epoch 86/100
162/163 [============================>.] - ETA: 0s - loss: 0.0670 - acc: 0
.9801Epoch 1/100
  1/163 [..............................] - ETA: 52s - loss: 5.3045 - acc:
0.5625
Epoch 00086: saving model to /content/data/model/weights.epoch_86.hdf5
163/163 [==============================] - 87s 531ms/step - loss: 0.0666 -
acc: 0.9803 - val_loss: 5.3045 - val_acc: 0.5625
Epoch 87/100
162/163 [============================>.] - ETA: 0s - loss: 0.0646 - acc: 0
.9797Epoch 1/100
  1/163 [..............................] - ETA: 54s - loss: 6.9546 - acc:
0.5625
Epoch 00087: saving model to /content/data/model/weights.epoch_87.hdf5
163/163 [==============================] - 86s 530ms/step - loss: 0.0651 -
acc: 0.9797 - val_loss: 6.9546 - val_acc: 0.5625
Epoch 88/100
162/163 [============================>.] - ETA: 0s - loss: 0.0834 - acc: 0
.9767Epoch 1/100
  1/163 [..............................] - ETA: 52s - loss: 6.5918 - acc:
0.5625
Epoch 00088: saving model to /content/data/model/weights.epoch_88.hdf5
```

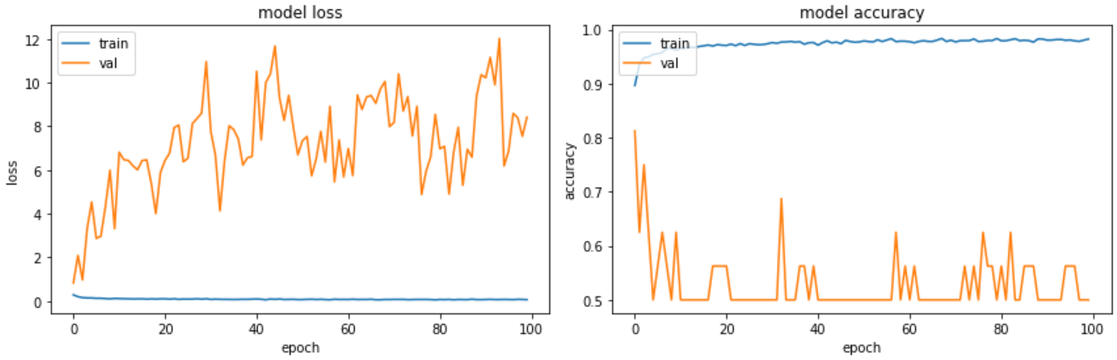
```
163/163 [==============================] - 87s 532ms/step - loss: 0.0829 -
acc: 0.9768 - val_loss: 6.5918 - val_acc: 0.5625
Epoch 89/100
162/163 [============================>.] - ETA: 0s - loss: 0.0662 - acc: 0
.9828Epoch 1/100
  1/163 [..............................] - ETA: 52s - loss: 9.3918 - acc:
0.5000
Epoch 00089: saving model to /content/data/model/weights.epoch_89.hdf5
163/163 [==============================] - 87s 532ms/step - loss: 0.0662 -
acc: 0.9827 - val_loss: 9.3918 - val_acc: 0.5000
Epoch 90/100
162/163 [============================>.] - ETA: 0s - loss: 0.0635 - acc: 0
.9826Epoch 1/100
  1/163 [..............................] - ETA: 55s - loss: 10.3696 - acc:
0.5000
Epoch 00090: saving model to /content/data/model/weights.epoch_90.hdf5
163/163 [==============================] - 86s 528ms/step - loss: 0.0645 -
acc: 0.9826 - val_loss: 10.3696 - val_acc: 0.5000
Epoch 91/100
162/163 [============================>.] - ETA: 0s - loss: 0.0709 - acc: 0
.9803Epoch 1/100
  1/163 [..............................] - ETA: 55s - loss: 10.2275 - acc:
0.5000
Epoch 00091: saving model to /content/data/model/weights.epoch_91.hdf5
163/163 [==============================] - 86s 529ms/step - loss: 0.0705 -
acc: 0.9804 - val_loss: 10.2275 - val_acc: 0.5000
Epoch 92/100
162/163 [============================>.] - ETA: 0s - loss: 0.0770 - acc: 0
.9807Epoch 1/100
  1/163 [..............................] - ETA: 54s - loss: 11.1581 - acc:
0.5000
Epoch 00092: saving model to /content/data/model/weights.epoch_92.hdf5
163/163 [==============================] - 87s 533ms/step - loss: 0.0768 -
acc: 0.9806 - val_loss: 11.1581 - val_acc: 0.5000
Epoch 93/100
162/163 [============================>.] - ETA: 0s - loss: 0.0675 - acc: 0
.9815Epoch 1/100
  1/163 [..............................] - ETA: 55s - loss: 9.9042 - acc:
0.5000
Epoch 00093: saving model to /content/data/model/weights.epoch_93.hdf5
163/163 [==============================] - 87s 534ms/step - loss: 0.0671 -
acc: 0.9816 - val_loss: 9.9042 - val_acc: 0.5000
Epoch 94/100
162/163 [============================>.] - ETA: 0s - loss: 0.0676 - acc: 0
.9819Epoch 1/100
  1/163 [..............................] - ETA: 55s - loss: 12.0309 - acc:
0.5000
Epoch 00094: saving model to /content/data/model/weights.epoch_94.hdf5
163/163 [==============================] - 86s 529ms/step - loss: 0.0676 -
acc: 0.9818 - val_loss: 12.0309 - val_acc: 0.5000
Epoch 95/100
162/163 [============================>.] - ETA: 0s - loss: 0.0725 - acc: 0
.9805Epoch 1/100
  1/163 [..............................] - ETA: 55s - loss: 6.1905 - acc:
```

```
0.5625
Epoch 00095: saving model to /content/data/model/weights.epoch_95.hdf5
163/163 [==============================] - 87s 531ms/step - loss: 0.0732 -
acc: 0.9803 - val_loss: 6.1905 - val_acc: 0.5625
Epoch 96/100
162/163 [============================>.] - ETA: 0s - loss: 0.0692 - acc: 0
.9807Epoch 1/100
  1/163 [..............................] - ETA: 53s - loss: 6.8690 - acc:
0.5625
Epoch 00096: saving model to /content/data/model/weights.epoch_96.hdf5
163/163 [==============================] - 87s 535ms/step - loss: 0.0688 -
acc: 0.9808 - val_loss: 6.8690 - val_acc: 0.5625
Epoch 97/100
162/163 [============================>.] - ETA: 0s - loss: 0.0640 - acc: 0
.9794Epoch 1/100
  1/163 [..............................] - ETA: 53s - loss: 8.5963 - acc:
0.5625
Epoch 00097: saving model to /content/data/model/weights.epoch_97.hdf5
163/163 [==============================] - 86s 527ms/step - loss: 0.0651 -
acc: 0.9791 - val_loss: 8.5963 - val_acc: 0.5625
Epoch 98/100
162/163 [============================>.] - ETA: 0s - loss: 0.0763 - acc: 0
.9784Epoch 1/100
  1/163 [..............................] - ETA: 53s - loss: 8.3895 - acc:
0.5000
Epoch 00098: saving model to /content/data/model/weights.epoch_98.hdf5
163/163 [==============================] - 85s 521ms/step - loss: 0.0763 -
acc: 0.9783 - val_loss: 8.3895 - val_acc: 0.5000
Epoch 99/100
162/163 [============================>.] - ETA: 0s - loss: 0.0727 - acc: 0
.9805Epoch 1/100
  1/163 [..............................] - ETA: 55s - loss: 7.5499 - acc:
0.5000
Epoch 00099: saving model to /content/data/model/weights.epoch_99.hdf5
163/163 [==============================] - 85s 522ms/step - loss: 0.0727 -
acc: 0.9804 - val_loss: 7.5499 - val_acc: 0.5000
Epoch 100/100
162/163 [============================>.] - ETA: 0s - loss: 0.0643 - acc: 0
.9824Epoch 1/100
  1/163 [..............................] - ETA: 57s - loss: 8.4232 - acc:
0.5000
Epoch 00100: saving model to /content/data/model/weights.epoch_100.hdf5
163/163 [==============================] - 86s 530ms/step - loss: 0.0639 -
acc: 0.9826 - val_loss: 8.4232 - val_acc: 0.5000
Loading the best model
epoch: 1, val_loss: 0.8304075598716736, val_acc: 0.8125
20/20 [==============================] - 8s 387ms/step - loss: 0.6455 - ac
c: 0.8093
20/20 [==============================] - 7s 358ms/step
CONFUSION MATRIX ------------------
[[136  98]
 [ 21 369]]

TEST METRICS ----------------------
```

```
Accuracy: 80.92948717948718%
Precision: 79.01498929336188%
Recall: 94.61538461538461%
F1-score: 86.11435239206534

TRAIN METRIC ----------------------
Train acc: 98.25536608695984%
```



png

9.11 Appendix K: NasNetMobile

```
from __future__ import absolute_import, division, print_function, unicode_
literals
import tensorflow as tf

# Extract dataset
import os
import tarfile

import keras_preprocessing
from keras_preprocessing.image import ImageDataGenerator # Data preprocess
ing and augmentation

import sklearn
import numpy as np
```

The default version of TensorFlow in Colab will soon switch to TensorFlow 2.x. We recommend you upgrade now or ensure your notebook will continue to use TensorFlow 1.x via the %tensorflow_version 1.x magic: more info.

```
print(tf.__version__)
```

```
1.15.0
```

```
# Make folder for chest xray data
!mkdir /content/data/

# Make directory to save weights
!mkdir /content/data/model

# Make directory to logs for Tensorboard
!mkdir /content/data/graph

# Download dataset
!wget --no-check-certificate \
    https://s3.eu-central-1.amazonaws.com/public.unit8.co/data/chest_xray.
tar.gz \
    -O /content/data/chest_xray.tar.gz

tar = tarfile.open("data/chest_xray.tar.gz")
tar.extractall(path='./data/')
os.remove('data/chest_xray.tar.gz')
```

```
--2019-11-10 03:37:48--  https://s3.eu-central-1.amazonaws.com/public.unit
8.co/data/chest_xray.tar.gz
Resolving s3.eu-central-1.amazonaws.com (s3.eu-central-1.amazonaws.com)...
52.219.72.151
Connecting to s3.eu-central-1.amazonaws.com (s3.eu-central-1.amazonaws.com
)|52.219.72.151|:443... connected.
HTTP request sent, awaiting response... 200 OK
Length: 1225393795 (1.1G) [application/x-gzip]
Saving to: '/content/data/chest_xray.tar.gz'
```

```
/content/data/chest 100%[===================>]   1.14G  21.9MB/s    in 56s

2019-11-10 03:38:45 (21.0 MB/s) - ‘/content/data/chest_xray.tar.gz’ saved
[1225393795/1225393795]
```

Change log: > training_datagen –> ImageDataGenerator

trainable layer –> All except base

xx layers NASNetMobile model - base, dense 2

Optimizer = RMSprop(learning_rate = 0.0001)

loss = categorical_crosscentropy

callback = [checkpoints]

epochs = 100

no class weight balancing

```
TRAINING_DIR = "/content/data/chest_xray/train"
VALIDATION_DIR = "/content/data/chest_xray/val"
TEST_DIR = "/content/data/chest_xray/test"

training_datagen = ImageDataGenerator(
    # preprocessing_function=tf.keras.applications.vgg16.preprocess_input,
    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,
    # vertical_flip=True
    fill_mode='nearest'
)

validation_datagen = ImageDataGenerator(
    rescale = 1./255
)

test_datagen = ImageDataGenerator(
    rescale = 1./255
)

# Create training data batch
# TODO: Try grayscaling the image to see what will happen
train_generator = training_datagen.flow_from_directory(
    TRAINING_DIR,
    target_size=(224,224),
    class_mode='categorical'
)

validation_generator = validation_datagen.flow_from_directory(
    VALIDATION_DIR,
    target_size=(224,224),
```

```
    class_mode='categorical'
)

test_generator = test_datagen.flow_from_directory(
    TEST_DIR,
    target_size=(224,224),
    class_mode='categorical',
    shuffle=False
)

train_shape = train_generator.image_shape

tf.keras.backend.clear_session() # Destroys the current TF graph and creat
es a new one.

base_model = tf.keras.applications.nasnet.NASNetMobile(weights='imagenet',
include_top=False, input_shape=train_shape)

x = base_model.output
x = tf.keras.layers.Flatten()(x)
# x = tf.keras.layers.Dense(64, activation='relu')(x)
# x = tf.keras.layers.Dropout(0.33)(x)
# x = tf.keras.layers.BatchNormalization()(x)
x = tf.keras.layers.Dense(2, 'softmax')(x)

model = tf.keras.Model(inputs=base_model.input, outputs=x)

# model.summary()

# for layer in model.layers[0:20]:
#     layer.trainable = False

for layer in base_model.layers:
  layer.trainable = False

optimizer = tf.keras.optimizers.RMSprop(learning_rate=0.0001) # Lower lear
ning rate by x10

model.compile(loss='categorical_crossentropy',
              optimizer=optimizer,
              metrics=['accuracy'])

# Callbacks stuff
# Function to save the weights of the model after each epoch
checkpoint = tf.keras.callbacks.ModelCheckpoint(
    '/content/data/model/weights.epoch_{epoch:02d}.hdf5',
    monitor='val_accuracy',
    save_best_only=False,
    save_weights_only=False,
    mode='auto',
    verbose=1
)

# Function to stop training early if there's no improvement
```

```
early_stopping_monitor = tf.keras.callbacks.EarlyStopping(patience = 3, mo
nitor = "val_loss", mode="auto", verbose = 1)

lr_reduce = tf.keras.callbacks.ReduceLROnPlateau(monitor='val_loss', facto
r=0.3, patience=2, verbose=1, mode='max')

classweight = sklearn.utils.class_weight.compute_class_weight('balanced',
np.unique(train_generator.labels), train_generator.labels)
print(classweight)

batch_size = 32
epochs = 100

# Training process
history = model.fit_generator(
    generator=train_generator,
    # steps_per_epoch=train_generator.samples//batch_size,
    epochs=epochs,
    # callbacks=[early_stopping_monitor],
    callbacks=[checkpoint],
    # shuffle=True,
    validation_data=validation_generator,
    # validation_steps= validation_generator//batch_size, #no because it's
gonna be 0... if leave alone its len(generator) which is equal to 1.
    # class_weight=classweight,
    verbose = 1
)

### Plot training
import matplotlib.pyplot as plt
def plot_learning_curves(history):
    plt.figure(figsize=(12,4))

    plt.subplot(1,2,1)
    plt.plot(history.history['loss'])
    plt.plot(history.history['val_loss'])
    plt.title('model loss')
    plt.ylabel('loss')
    plt.xlabel('epoch')
    plt.legend(['train', 'val'], loc='upper left')

    plt.subplot(1,2,2)
    plt.plot(history.history['acc'])
    plt.plot(history.history['val_acc'])
    plt.title('model accuracy')
    plt.ylabel('accuracy')
    plt.xlabel('epoch')
    plt.legend(['train', 'val'], loc='upper left')

    plt.tight_layout()

plot_learning_curves(history)

## Load best weight
```

```
idx = np.argmin(history.history['val_loss'])
model.load_weights("/content/data/model/weights.epoch_{:02d}.hdf5".format(
idx + 1))

print("Loading the best model")
print("epoch: {}, val_loss: {}, val_acc: {}".format(idx + 1, history.histo
ry['val_loss'][idx], history.history['val_acc'][idx]))

## Evaluate the model
test_loss, test_acc = model.evaluate_generator(generator=test_generator, v
erbose=1)

## Analytics
from sklearn.metrics import accuracy_score, confusion_matrix

test_generator.reset()
test_preds = model.predict_generator(test_generator, verbose=1)
test_preds = np.argmax(test_preds,axis=1)

acc = accuracy_score(test_generator.classes, test_preds)*100
cm = confusion_matrix(test_generator.classes, test_preds)
tn, fp, fn, tp = cm.ravel()

print('CONFUSION MATRIX ------------------')
print(cm)
# plot_confusion_matrix(cm, target_names=['NORMAL', 'PNEUMONIA'], normaliz
e=False)


print('\nTEST METRICS ----------------------')
precision = tp/(tp+fp)*100
recall = tp/(tp+fn)*100
print('Accuracy: {}%'.format(acc))
print('Precision: {}%'.format(precision))
print('Recall: {}%'.format(recall))
print('F1-score: {}'.format(2*precision*recall/(precision+recall)))

print('\nTRAIN METRIC ----------------------')
print('Train acc: {}%'.format(np.round((history.history['acc'][-1])*100, 1
4)))
```

```
Found 5216 images belonging to 2 classes.
Found 16 images belonging to 2 classes.
Found 624 images belonging to 2 classes.
[1.9448173  0.67303226]
Epoch 1/100
162/163 [============================>.] - ETA: 0s - loss: 0.3146 - acc: 0
.8767Epoch 1/100
  1/163 [..............................] - ETA: 22:20 - loss: 1.0502 - acc
: 0.5625
Epoch 00001: saving model to /content/data/model/weights.epoch_01.hdf5
163/163 [==============================] - 305s 2s/step - loss: 0.3139 - a
cc: 0.8769 - val_loss: 1.0502 - val_acc: 0.5625
Epoch 2/100
```

```
162/163 [============================>.] - ETA: 0s - loss: 0.2164 - acc: 0
.9198Epoch 1/100
  1/163 [..............................] - ETA: 45s - loss: 2.3544 - acc:
0.5000
Epoch 00002: saving model to /content/data/model/weights.epoch_02.hdf5
163/163 [==============================] - 92s 563ms/step - loss: 0.2159 -
acc: 0.9199 - val_loss: 2.3544 - val_acc: 0.5000
Epoch 3/100
162/163 [============================>.] - ETA: 0s - loss: 0.1909 - acc: 0
.9290Epoch 1/100
  1/163 [..............................] - ETA: 44s - loss: 4.4237 - acc:
0.5000
Epoch 00003: saving model to /content/data/model/weights.epoch_03.hdf5
163/163 [==============================] - 96s 592ms/step - loss: 0.1910 -
acc: 0.9291 - val_loss: 4.4237 - val_acc: 0.5000
Epoch 4/100
162/163 [============================>.] - ETA: 0s - loss: 0.1788 - acc: 0
.9358Epoch 1/100
  1/163 [..............................] - ETA: 46s - loss: 1.4570 - acc:
0.6250
Epoch 00004: saving model to /content/data/model/weights.epoch_04.hdf5
163/163 [==============================] - 97s 595ms/step - loss: 0.1780 -
acc: 0.9360 - val_loss: 1.4570 - val_acc: 0.6250
Epoch 5/100
162/163 [============================>.] - ETA: 0s - loss: 0.1630 - acc: 0
.9412Epoch 1/100
  1/163 [..............................] - ETA: 45s - loss: 3.8332 - acc:
0.5000
Epoch 00005: saving model to /content/data/model/weights.epoch_05.hdf5
163/163 [==============================] - 98s 599ms/step - loss: 0.1628 -
acc: 0.9411 - val_loss: 3.8332 - val_acc: 0.5000
Epoch 6/100
162/163 [============================>.] - ETA: 0s - loss: 0.1509 - acc: 0
.9452Epoch 1/100
  1/163 [..............................] - ETA: 45s - loss: 3.3706 - acc:
0.5000
Epoch 00006: saving model to /content/data/model/weights.epoch_06.hdf5
163/163 [==============================] - 98s 599ms/step - loss: 0.1508 -
acc: 0.9452 - val_loss: 3.3706 - val_acc: 0.5000
Epoch 7/100
162/163 [============================>.] - ETA: 0s - loss: 0.1569 - acc: 0
.9460Epoch 1/100
  1/163 [..............................] - ETA: 43s - loss: 3.0819 - acc:
0.5000
Epoch 00007: saving model to /content/data/model/weights.epoch_07.hdf5
163/163 [==============================] - 98s 600ms/step - loss: 0.1577 -
acc: 0.9457 - val_loss: 3.0819 - val_acc: 0.5000
Epoch 8/100
162/163 [============================>.] - ETA: 0s - loss: 0.1486 - acc: 0
.9487Epoch 1/100
  1/163 [..............................] - ETA: 44s - loss: 4.3488 - acc:
0.5000
Epoch 00008: saving model to /content/data/model/weights.epoch_08.hdf5
163/163 [==============================] - 98s 604ms/step - loss: 0.1477 -
```

```
acc: 0.9490 - val_loss: 4.3488 - val_acc: 0.5000
Epoch 9/100
162/163 [============================>.] - ETA: 0s - loss: 0.1443 - acc: 0
.9504Epoch 1/100
  1/163 [..............................] - ETA: 44s - loss: 4.6339 - acc:
0.5000
Epoch 00009: saving model to /content/data/model/weights.epoch_09.hdf5
163/163 [==============================] - 98s 603ms/step - loss: 0.1456 -
acc: 0.9502 - val_loss: 4.6339 - val_acc: 0.5000
Epoch 10/100
162/163 [============================>.] - ETA: 0s - loss: 0.1515 - acc: 0
.9483Epoch 1/100
  1/163 [..............................] - ETA: 49s - loss: 3.0252 - acc:
0.5000
Epoch 00010: saving model to /content/data/model/weights.epoch_10.hdf5
163/163 [==============================] - 99s 605ms/step - loss: 0.1509 -
acc: 0.9486 - val_loss: 3.0252 - val_acc: 0.5000
Epoch 11/100
162/163 [============================>.] - ETA: 0s - loss: 0.1376 - acc: 0
.9537Epoch 1/100
  1/163 [..............................] - ETA: 47s - loss: 4.7336 - acc:
0.5000
Epoch 00011: saving model to /content/data/model/weights.epoch_11.hdf5
163/163 [==============================] - 99s 609ms/step - loss: 0.1393 -
acc: 0.9534 - val_loss: 4.7336 - val_acc: 0.5000
Epoch 12/100
162/163 [============================>.] - ETA: 0s - loss: 0.1319 - acc: 0
.9520Epoch 1/100
  1/163 [..............................] - ETA: 48s - loss: 4.2742 - acc:
0.5000
Epoch 00012: saving model to /content/data/model/weights.epoch_12.hdf5
163/163 [==============================] - 98s 604ms/step - loss: 0.1325 -
acc: 0.9519 - val_loss: 4.2742 - val_acc: 0.5000
Epoch 13/100
162/163 [============================>.] - ETA: 0s - loss: 0.1524 - acc: 0
.9493Epoch 1/100
  1/163 [..............................] - ETA: 47s - loss: 3.1455 - acc:
0.5000
Epoch 00013: saving model to /content/data/model/weights.epoch_13.hdf5
163/163 [==============================] - 99s 609ms/step - loss: 0.1528 -
acc: 0.9494 - val_loss: 3.1455 - val_acc: 0.5000
Epoch 14/100
162/163 [============================>.] - ETA: 0s - loss: 0.1245 - acc: 0
.9554Epoch 1/100
  1/163 [..............................] - ETA: 45s - loss: 3.1773 - acc:
0.5000
Epoch 00014: saving model to /content/data/model/weights.epoch_14.hdf5
163/163 [==============================] - 99s 609ms/step - loss: 0.1248 -
acc: 0.9553 - val_loss: 3.1773 - val_acc: 0.5000
Epoch 15/100
162/163 [============================>.] - ETA: 0s - loss: 0.1366 - acc: 0
.9512Epoch 1/100
  1/163 [..............................] - ETA: 45s - loss: 2.9495 - acc:
0.5000
```

```
Epoch 00015: saving model to /content/data/model/weights.epoch_15.hdf5
163/163 [==============================] - 99s 606ms/step - loss: 0.1358 -
acc: 0.9515 - val_loss: 2.9495 - val_acc: 0.5000
Epoch 16/100
162/163 [============================>.] - ETA: 0s - loss: 0.1260 - acc: 0
.9549Epoch 1/100
  1/163 [..............................] - ETA: 47s - loss: 3.1615 - acc:
0.5000
Epoch 00016: saving model to /content/data/model/weights.epoch_16.hdf5
163/163 [==============================] - 100s 611ms/step - loss: 0.1268
- acc: 0.9548 - val_loss: 3.1615 - val_acc: 0.5000
Epoch 17/100
162/163 [============================>.] - ETA: 0s - loss: 0.1318 - acc: 0
.9560Epoch 1/100
  1/163 [..............................] - ETA: 43s - loss: 4.2920 - acc:
0.5000
Epoch 00017: saving model to /content/data/model/weights.epoch_17.hdf5
163/163 [==============================] - 99s 609ms/step - loss: 0.1312 -
acc: 0.9563 - val_loss: 4.2920 - val_acc: 0.5000
Epoch 18/100
162/163 [============================>.] - ETA: 0s - loss: 0.1280 - acc: 0
.9570Epoch 1/100
  1/163 [..............................] - ETA: 46s - loss: 2.1244 - acc:
0.5625
Epoch 00018: saving model to /content/data/model/weights.epoch_18.hdf5
163/163 [==============================] - 99s 606ms/step - loss: 0.1293 -
acc: 0.9567 - val_loss: 2.1244 - val_acc: 0.5625
Epoch 19/100
162/163 [============================>.] - ETA: 0s - loss: 0.1296 - acc: 0
.9587Epoch 1/100
  1/163 [..............................] - ETA: 45s - loss: 5.6963 - acc:
0.5000
Epoch 00019: saving model to /content/data/model/weights.epoch_19.hdf5
163/163 [==============================] - 100s 612ms/step - loss: 0.1301
- acc: 0.9580 - val_loss: 5.6963 - val_acc: 0.5000
Epoch 20/100
162/163 [============================>.] - ETA: 0s - loss: 0.1212 - acc: 0
.9632Epoch 1/100
  1/163 [..............................] - ETA: 45s - loss: 3.8702 - acc:
0.5000
Epoch 00020: saving model to /content/data/model/weights.epoch_20.hdf5
163/163 [==============================] - 100s 611ms/step - loss: 0.1205
- acc: 0.9634 - val_loss: 3.8702 - val_acc: 0.5000
Epoch 21/100
162/163 [============================>.] - ETA: 0s - loss: 0.1264 - acc: 0
.9587Epoch 1/100
  1/163 [..............................] - ETA: 46s - loss: 5.0109 - acc:
0.5000
Epoch 00021: saving model to /content/data/model/weights.epoch_21.hdf5
163/163 [==============================] - 99s 610ms/step - loss: 0.1264 -
acc: 0.9586 - val_loss: 5.0109 - val_acc: 0.5000
Epoch 22/100
162/163 [============================>.] - ETA: 0s - loss: 0.1049 - acc: 0
.9659Epoch 1/100
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  1/163 [..............................] - ETA: 45s - loss: 3.9262 - acc: 
0.5000
Epoch 00022: saving model to /content/data/model/weights.epoch_22.hdf5
163/163 [==============================] - 100s 613ms/step - loss: 0.1048 
- acc: 0.9657 - val_loss: 3.9262 - val_acc: 0.5000
Epoch 23/100
162/163 [============================>.] - ETA: 0s - loss: 0.1148 - acc: 0
.9616Epoch 1/100
  1/163 [..............................] - ETA: 50s - loss: 3.9483 - acc: 
0.5000
Epoch 00023: saving model to /content/data/model/weights.epoch_23.hdf5
163/163 [==============================] - 100s 611ms/step - loss: 0.1144 
- acc: 0.9617 - val_loss: 3.9483 - val_acc: 0.5000
Epoch 24/100
162/163 [============================>.] - ETA: 0s - loss: 0.1204 - acc: 0
.9579Epoch 1/100
  1/163 [..............................] - ETA: 45s - loss: 5.2347 - acc: 
0.5000
Epoch 00024: saving model to /content/data/model/weights.epoch_24.hdf5
163/163 [==============================] - 99s 610ms/step - loss: 0.1197 - 
acc: 0.9582 - val_loss: 5.2347 - val_acc: 0.5000
Epoch 25/100
162/163 [============================>.] - ETA: 0s - loss: 0.1196 - acc: 0
.9626Epoch 1/100
  1/163 [..............................] - ETA: 46s - loss: 3.0126 - acc: 
0.5000
Epoch 00025: saving model to /content/data/model/weights.epoch_25.hdf5
163/163 [==============================] - 100s 613ms/step - loss: 0.1204 
- acc: 0.9622 - val_loss: 3.0126 - val_acc: 0.5000
Epoch 26/100
162/163 [============================>.] - ETA: 0s - loss: 0.1260 - acc: 0
.9576Epoch 1/100
  1/163 [..............................] - ETA: 48s - loss: 3.4674 - acc: 
0.5000
Epoch 00026: saving model to /content/data/model/weights.epoch_26.hdf5
163/163 [==============================] - 100s 613ms/step - loss: 0.1256 
- acc: 0.9576 - val_loss: 3.4674 - val_acc: 0.5000
Epoch 27/100
162/163 [============================>.] - ETA: 0s - loss: 0.1122 - acc: 0
.9641Epoch 1/100
  1/163 [..............................] - ETA: 49s - loss: 6.6356 - acc: 
0.5000
Epoch 00027: saving model to /content/data/model/weights.epoch_27.hdf5
163/163 [==============================] - 100s 613ms/step - loss: 0.1116 
- acc: 0.9643 - val_loss: 6.6356 - val_acc: 0.5000
Epoch 28/100
162/163 [============================>.] - ETA: 0s - loss: 0.1108 - acc: 0
.9655Epoch 1/100
  1/163 [..............................] - ETA: 46s - loss: 4.9004 - acc: 
0.5000
Epoch 00028: saving model to /content/data/model/weights.epoch_28.hdf5
163/163 [==============================] - 99s 610ms/step - loss: 0.1103 - 
acc: 0.9657 - val_loss: 4.9004 - val_acc: 0.5000
Epoch 29/100
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162/163 [============================>.] - ETA: 0s - loss: 0.1154 - acc: 0
.9603Epoch 1/100
  1/163 [..............................] - ETA: 45s - loss: 4.8081 - acc:
0.5000
Epoch 00029: saving model to /content/data/model/weights.epoch_29.hdf5
163/163 [==============================] - 100s 611ms/step - loss: 0.1148
- acc: 0.9605 - val_loss: 4.8081 - val_acc: 0.5000
Epoch 30/100
162/163 [============================>.] - ETA: 0s - loss: 0.1158 - acc: 0
.9643Epoch 1/100
  1/163 [..............................] - ETA: 45s - loss: 5.5584 - acc:
0.5000
Epoch 00030: saving model to /content/data/model/weights.epoch_30.hdf5
163/163 [==============================] - 98s 603ms/step - loss: 0.1152 -
acc: 0.9645 - val_loss: 5.5584 - val_acc: 0.5000
Epoch 31/100
162/163 [============================>.] - ETA: 0s - loss: 0.1228 - acc: 0
.9608Epoch 1/100
  1/163 [..............................] - ETA: 45s - loss: 3.7674 - acc:
0.5000
Epoch 00031: saving model to /content/data/model/weights.epoch_31.hdf5
163/163 [==============================] - 96s 586ms/step - loss: 0.1231 -
acc: 0.9603 - val_loss: 3.7674 - val_acc: 0.5000
Epoch 32/100
162/163 [============================>.] - ETA: 0s - loss: 0.1206 - acc: 0
.9603Epoch 1/100
  1/163 [..............................] - ETA: 45s - loss: 5.7070 - acc:
0.5000
Epoch 00032: saving model to /content/data/model/weights.epoch_32.hdf5
163/163 [==============================] - 93s 572ms/step - loss: 0.1201 -
acc: 0.9603 - val_loss: 5.7070 - val_acc: 0.5000
Epoch 33/100
162/163 [============================>.] - ETA: 0s - loss: 0.1221 - acc: 0
.9637Epoch 1/100
  1/163 [..............................] - ETA: 44s - loss: 4.6656 - acc:
0.5000
Epoch 00033: saving model to /content/data/model/weights.epoch_33.hdf5
163/163 [==============================] - 94s 574ms/step - loss: 0.1218 -
acc: 0.9636 - val_loss: 4.6656 - val_acc: 0.5000
Epoch 34/100
162/163 [============================>.] - ETA: 0s - loss: 0.1094 - acc: 0
.9651Epoch 1/100
  1/163 [..............................] - ETA: 43s - loss: 4.5878 - acc:
0.5000
Epoch 00034: saving model to /content/data/model/weights.epoch_34.hdf5
163/163 [==============================] - 92s 567ms/step - loss: 0.1108 -
acc: 0.9647 - val_loss: 4.5878 - val_acc: 0.5000
Epoch 35/100
162/163 [============================>.] - ETA: 0s - loss: 0.1171 - acc: 0
.9612Epoch 1/100
  1/163 [..............................] - ETA: 43s - loss: 4.3260 - acc:
0.5000
Epoch 00035: saving model to /content/data/model/weights.epoch_35.hdf5
163/163 [==============================] - 92s 566ms/step - loss: 0.1166 -
```

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acc: 0.9615 - val_loss: 4.3260 - val_acc: 0.5000
Epoch 36/100
162/163 [============================>.] - ETA: 0s - loss: 0.1058 - acc: 0
.9651Epoch 1/100
  1/163 [..............................] - ETA: 44s - loss: 4.4338 - acc:
0.5000
Epoch 00036: saving model to /content/data/model/weights.epoch_36.hdf5
163/163 [==============================] - 93s 570ms/step - loss: 0.1051 -
acc: 0.9653 - val_loss: 4.4338 - val_acc: 0.5000
Epoch 37/100
162/163 [============================>.] - ETA: 0s - loss: 0.1196 - acc: 0
.9618Epoch 1/100
  1/163 [..............................] - ETA: 1:29 - loss: 5.4527 - acc:
0.5000
Epoch 00037: saving model to /content/data/model/weights.epoch_37.hdf5
163/163 [==============================] - 92s 567ms/step - loss: 0.1190 -
acc: 0.9618 - val_loss: 5.4527 - val_acc: 0.5000
Epoch 38/100
162/163 [============================>.] - ETA: 0s - loss: 0.1191 - acc: 0
.9626Epoch 1/100
  1/163 [..............................] - ETA: 41s - loss: 3.9768 - acc:
0.5000
Epoch 00038: saving model to /content/data/model/weights.epoch_38.hdf5
163/163 [==============================] - 92s 565ms/step - loss: 0.1190 -
acc: 0.9626 - val_loss: 3.9768 - val_acc: 0.5000
Epoch 39/100
162/163 [============================>.] - ETA: 0s - loss: 0.1071 - acc: 0
.9628Epoch 1/100
  1/163 [..............................] - ETA: 43s - loss: 4.7560 - acc:
0.5000
Epoch 00039: saving model to /content/data/model/weights.epoch_39.hdf5
163/163 [==============================] - 92s 565ms/step - loss: 0.1068 -
acc: 0.9628 - val_loss: 4.7560 - val_acc: 0.5000
Epoch 40/100
162/163 [============================>.] - ETA: 0s - loss: 0.1069 - acc: 0
.9653Epoch 1/100
  1/163 [..............................] - ETA: 44s - loss: 4.4206 - acc:
0.5000
Epoch 00040: saving model to /content/data/model/weights.epoch_40.hdf5
163/163 [==============================] - 92s 567ms/step - loss: 0.1066 -
acc: 0.9653 - val_loss: 4.4206 - val_acc: 0.5000
Epoch 41/100
162/163 [============================>.] - ETA: 0s - loss: 0.1115 - acc: 0
.9630Epoch 1/100
  1/163 [..............................] - ETA: 43s - loss: 5.2622 - acc:
0.5000
Epoch 00041: saving model to /content/data/model/weights.epoch_41.hdf5
163/163 [==============================] - 92s 565ms/step - loss: 0.1117 -
acc: 0.9628 - val_loss: 5.2622 - val_acc: 0.5000
Epoch 42/100
162/163 [============================>.] - ETA: 0s - loss: 0.1075 - acc: 0
.9639Epoch 1/100
  1/163 [..............................] - ETA: 42s - loss: 5.3675 - acc:
0.5000
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Epoch 00042: saving model to /content/data/model/weights.epoch_42.hdf5
163/163 [==============================] - 92s 565ms/step - loss: 0.1068 -
acc: 0.9641 - val_loss: 5.3675 - val_acc: 0.5000
Epoch 43/100
162/163 [============================>.] - ETA: 0s - loss: 0.1101 - acc: 0
.9645Epoch 1/100
  1/163 [..............................] - ETA: 40s - loss: 5.8816 - acc:
0.5000
Epoch 00043: saving model to /content/data/model/weights.epoch_43.hdf5
163/163 [==============================] - 92s 566ms/step - loss: 0.1098 -
acc: 0.9645 - val_loss: 5.8816 - val_acc: 0.5000
Epoch 44/100
162/163 [============================>.] - ETA: 0s - loss: 0.1145 - acc: 0
.9622Epoch 1/100
  1/163 [..............................] - ETA: 43s - loss: 5.3769 - acc:
0.5000
Epoch 00044: saving model to /content/data/model/weights.epoch_44.hdf5
163/163 [==============================] - 92s 564ms/step - loss: 0.1151 -
acc: 0.9622 - val_loss: 5.3769 - val_acc: 0.5000
Epoch 45/100
162/163 [============================>.] - ETA: 0s - loss: 0.1148 - acc: 0
.9610Epoch 1/100
  1/163 [..............................] - ETA: 43s - loss: 4.0523 - acc:
0.5000
Epoch 00045: saving model to /content/data/model/weights.epoch_45.hdf5
163/163 [==============================] - 92s 564ms/step - loss: 0.1142 -
acc: 0.9613 - val_loss: 4.0523 - val_acc: 0.5000
Epoch 46/100
162/163 [============================>.] - ETA: 0s - loss: 0.1236 - acc: 0
.9628Epoch 1/100
  1/163 [..............................] - ETA: 43s - loss: 2.9665 - acc:
0.5000
Epoch 00046: saving model to /content/data/model/weights.epoch_46.hdf5
163/163 [==============================] - 92s 567ms/step - loss: 0.1229 -
acc: 0.9630 - val_loss: 2.9665 - val_acc: 0.5000
Epoch 47/100
162/163 [============================>.] - ETA: 0s - loss: 0.0909 - acc: 0
.9705Epoch 1/100
  1/163 [..............................] - ETA: 46s - loss: 5.1887 - acc:
0.5000
Epoch 00047: saving model to /content/data/model/weights.epoch_47.hdf5
163/163 [==============================] - 93s 568ms/step - loss: 0.0907 -
acc: 0.9705 - val_loss: 5.1887 - val_acc: 0.5000
Epoch 48/100
162/163 [============================>.] - ETA: 0s - loss: 0.1134 - acc: 0
.9632Epoch 1/100
  1/163 [..............................] - ETA: 43s - loss: 5.1818 - acc:
0.5000
Epoch 00048: saving model to /content/data/model/weights.epoch_48.hdf5
163/163 [==============================] - 92s 566ms/step - loss: 0.1128 -
acc: 0.9634 - val_loss: 5.1818 - val_acc: 0.5000
Epoch 49/100
162/163 [============================>.] - ETA: 0s - loss: 0.1170 - acc: 0
.9622Epoch 1/100
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  1/163 [..............................] - ETA: 43s - loss: 4.7142 - acc: 
0.5000
Epoch 00049: saving model to /content/data/model/weights.epoch_49.hdf5
163/163 [==============================] - 92s 565ms/step - loss: 0.1165 - 
acc: 0.9622 - val_loss: 4.7142 - val_acc: 0.5000
Epoch 50/100
162/163 [============================>.] - ETA: 0s - loss: 0.1063 - acc: 0
.9672Epoch 1/100
  1/163 [..............................] - ETA: 44s - loss: 4.9555 - acc: 
0.5000
Epoch 00050: saving model to /content/data/model/weights.epoch_50.hdf5
163/163 [==============================] - 92s 564ms/step - loss: 0.1075 - 
acc: 0.9670 - val_loss: 4.9555 - val_acc: 0.5000
Epoch 51/100
162/163 [============================>.] - ETA: 0s - loss: 0.1165 - acc: 0
.9674Epoch 1/100
  1/163 [..............................] - ETA: 46s - loss: 5.5071 - acc: 
0.5000
Epoch 00051: saving model to /content/data/model/weights.epoch_51.hdf5
163/163 [==============================] - 92s 564ms/step - loss: 0.1162 - 
acc: 0.9674 - val_loss: 5.5071 - val_acc: 0.5000
Epoch 52/100
162/163 [============================>.] - ETA: 0s - loss: 0.1059 - acc: 0
.9662Epoch 1/100
  1/163 [..............................] - ETA: 44s - loss: 5.6460 - acc: 
0.5000
Epoch 00052: saving model to /content/data/model/weights.epoch_52.hdf5
163/163 [==============================] - 92s 565ms/step - loss: 0.1067 - 
acc: 0.9657 - val_loss: 5.6460 - val_acc: 0.5000
Epoch 53/100
162/163 [============================>.] - ETA: 0s - loss: 0.1161 - acc: 0
.9651Epoch 1/100
  1/163 [..............................] - ETA: 43s - loss: 3.9479 - acc: 
0.5000
Epoch 00053: saving model to /content/data/model/weights.epoch_53.hdf5
163/163 [==============================] - 92s 565ms/step - loss: 0.1154 - 
acc: 0.9653 - val_loss: 3.9479 - val_acc: 0.5000
Epoch 54/100
162/163 [============================>.] - ETA: 0s - loss: 0.1036 - acc: 0
.9649Epoch 1/100
  1/163 [..............................] - ETA: 44s - loss: 4.5147 - acc: 
0.5000
Epoch 00054: saving model to /content/data/model/weights.epoch_54.hdf5
163/163 [==============================] - 92s 563ms/step - loss: 0.1030 - 
acc: 0.9651 - val_loss: 4.5147 - val_acc: 0.5000
Epoch 55/100
162/163 [============================>.] - ETA: 0s - loss: 0.1141 - acc: 0
.9632Epoch 1/100
  1/163 [..............................] - ETA: 43s - loss: 3.8783 - acc: 
0.5000
Epoch 00055: saving model to /content/data/model/weights.epoch_55.hdf5
163/163 [==============================] - 92s 565ms/step - loss: 0.1140 - 
acc: 0.9630 - val_loss: 3.8783 - val_acc: 0.5000
Epoch 56/100
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162/163 [============================>.] - ETA: 0s - loss: 0.1104 - acc: 0
.9645Epoch 1/100
  1/163 [..............................] - ETA: 43s - loss: 5.0406 - acc:
0.5000
Epoch 00056: saving model to /content/data/model/weights.epoch_56.hdf5
163/163 [==============================] - 92s 563ms/step - loss: 0.1114 -
acc: 0.9645 - val_loss: 5.0406 - val_acc: 0.5000
Epoch 57/100
162/163 [============================>.] - ETA: 0s - loss: 0.0974 - acc: 0
.9689Epoch 1/100
  1/163 [..............................] - ETA: 43s - loss: 5.4624 - acc:
0.5000
Epoch 00057: saving model to /content/data/model/weights.epoch_57.hdf5
163/163 [==============================] - 92s 564ms/step - loss: 0.0968 -
acc: 0.9691 - val_loss: 5.4624 - val_acc: 0.5000
Epoch 58/100
162/163 [============================>.] - ETA: 0s - loss: 0.0989 - acc: 0
.9709Epoch 1/100
  1/163 [..............................] - ETA: 43s - loss: 3.2762 - acc:
0.5000
Epoch 00058: saving model to /content/data/model/weights.epoch_58.hdf5
163/163 [==============================] - 92s 565ms/step - loss: 0.0992 -
acc: 0.9705 - val_loss: 3.2762 - val_acc: 0.5000
Epoch 59/100
162/163 [============================>.] - ETA: 0s - loss: 0.0981 - acc: 0
.9682Epoch 1/100
  1/163 [..............................] - ETA: 44s - loss: 5.6076 - acc:
0.5000
Epoch 00059: saving model to /content/data/model/weights.epoch_59.hdf5
163/163 [==============================] - 92s 564ms/step - loss: 0.0977 -
acc: 0.9682 - val_loss: 5.6076 - val_acc: 0.5000
Epoch 60/100
162/163 [============================>.] - ETA: 0s - loss: 0.1098 - acc: 0
.9655Epoch 1/100
  1/163 [..............................] - ETA: 44s - loss: 6.1544 - acc:
0.5000
Epoch 00060: saving model to /content/data/model/weights.epoch_60.hdf5
163/163 [==============================] - 92s 564ms/step - loss: 0.1102 -
acc: 0.9653 - val_loss: 6.1544 - val_acc: 0.5000
Epoch 61/100
162/163 [============================>.] - ETA: 0s - loss: 0.0991 - acc: 0
.9697Epoch 1/100
  1/163 [..............................] - ETA: 42s - loss: 5.8724 - acc:
0.5000
Epoch 00061: saving model to /content/data/model/weights.epoch_61.hdf5
163/163 [==============================] - 92s 567ms/step - loss: 0.0991 -
acc: 0.9697 - val_loss: 5.8724 - val_acc: 0.5000
Epoch 62/100
162/163 [============================>.] - ETA: 0s - loss: 0.1002 - acc: 0
.9668Epoch 1/100
  1/163 [..............................] - ETA: 42s - loss: 3.5251 - acc:
0.5000
Epoch 00062: saving model to /content/data/model/weights.epoch_62.hdf5
163/163 [==============================] - 92s 563ms/step - loss: 0.0996 -
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acc: 0.9670 - val_loss: 3.5251 - val_acc: 0.5000
Epoch 63/100
162/163 [============================>.] - ETA: 0s - loss: 0.1082 - acc: 0
.9641Epoch 1/100
  1/163 [..............................] - ETA: 45s - loss: 3.0714 - acc:
0.5625
Epoch 00063: saving model to /content/data/model/weights.epoch_63.hdf5
163/163 [==============================] - 92s 563ms/step - loss: 0.1094 -
acc: 0.9640 - val_loss: 3.0714 - val_acc: 0.5625
Epoch 64/100
162/163 [============================>.] - ETA: 0s - loss: 0.0973 - acc: 0
.9691Epoch 1/100
  1/163 [..............................] - ETA: 43s - loss: 5.2249 - acc:
0.5000
Epoch 00064: saving model to /content/data/model/weights.epoch_64.hdf5
163/163 [==============================] - 92s 565ms/step - loss: 0.0979 -
acc: 0.9689 - val_loss: 5.2249 - val_acc: 0.5000
Epoch 65/100
162/163 [============================>.] - ETA: 0s - loss: 0.1079 - acc: 0
.9639Epoch 1/100
  1/163 [..............................] - ETA: 43s - loss: 2.9878 - acc:
0.5625
Epoch 00065: saving model to /content/data/model/weights.epoch_65.hdf5
163/163 [==============================] - 92s 564ms/step - loss: 0.1073 -
acc: 0.9641 - val_loss: 2.9878 - val_acc: 0.5625
Epoch 66/100
162/163 [============================>.] - ETA: 0s - loss: 0.0854 - acc: 0
.9713Epoch 1/100
  1/163 [..............................] - ETA: 42s - loss: 3.7700 - acc:
0.5000
Epoch 00066: saving model to /content/data/model/weights.epoch_66.hdf5
163/163 [==============================] - 92s 563ms/step - loss: 0.0855 -
acc: 0.9712 - val_loss: 3.7700 - val_acc: 0.5000
Epoch 67/100
162/163 [============================>.] - ETA: 0s - loss: 0.0991 - acc: 0
.9697Epoch 1/100
  1/163 [..............................] - ETA: 45s - loss: 4.4717 - acc:
0.5000
Epoch 00067: saving model to /content/data/model/weights.epoch_67.hdf5
163/163 [==============================] - 92s 566ms/step - loss: 0.0986 -
acc: 0.9699 - val_loss: 4.4717 - val_acc: 0.5000
Epoch 68/100
162/163 [============================>.] - ETA: 0s - loss: 0.1005 - acc: 0
.9684Epoch 1/100
  1/163 [..............................] - ETA: 45s - loss: 3.5143 - acc:
0.5000
Epoch 00068: saving model to /content/data/model/weights.epoch_68.hdf5
163/163 [==============================] - 92s 562ms/step - loss: 0.1022 -
acc: 0.9680 - val_loss: 3.5143 - val_acc: 0.5000
Epoch 69/100
162/163 [============================>.] - ETA: 0s - loss: 0.0997 - acc: 0
.9693Epoch 1/100
  1/163 [..............................] - ETA: 44s - loss: 4.4872 - acc:
0.5000
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Epoch 00069: saving model to /content/data/model/weights.epoch_69.hdf5
163/163 [==============================] - 92s 563ms/step - loss: 0.0999 -
acc: 0.9691 - val_loss: 4.4872 - val_acc: 0.5000
Epoch 70/100
162/163 [============================>.] - ETA: 0s - loss: 0.1004 - acc: 0
.9672Epoch 1/100
  1/163 [..............................] - ETA: 40s - loss: 3.9240 - acc:
0.5625
Epoch 00070: saving model to /content/data/model/weights.epoch_70.hdf5
163/163 [==============================] - 92s 563ms/step - loss: 0.1012 -
acc: 0.9672 - val_loss: 3.9240 - val_acc: 0.5625
Epoch 71/100
162/163 [============================>.] - ETA: 0s - loss: 0.0929 - acc: 0
.9701Epoch 1/100
  1/163 [..............................] - ETA: 46s - loss: 2.7305 - acc:
0.5625
Epoch 00071: saving model to /content/data/model/weights.epoch_71.hdf5
163/163 [==============================] - 92s 565ms/step - loss: 0.0950 -
acc: 0.9697 - val_loss: 2.7305 - val_acc: 0.5625
Epoch 72/100
162/163 [============================>.] - ETA: 0s - loss: 0.1206 - acc: 0
.9637Epoch 1/100
  1/163 [..............................] - ETA: 43s - loss: 5.1932 - acc:
0.5000
Epoch 00072: saving model to /content/data/model/weights.epoch_72.hdf5
163/163 [==============================] - 92s 564ms/step - loss: 0.1200 -
acc: 0.9640 - val_loss: 5.1932 - val_acc: 0.5000
Epoch 73/100
162/163 [============================>.] - ETA: 0s - loss: 0.0907 - acc: 0
.9691Epoch 1/100
  1/163 [..............................] - ETA: 44s - loss: 5.8781 - acc:
0.5000
Epoch 00073: saving model to /content/data/model/weights.epoch_73.hdf5
163/163 [==============================] - 92s 563ms/step - loss: 0.0902 -
acc: 0.9693 - val_loss: 5.8781 - val_acc: 0.5000
Epoch 74/100
162/163 [============================>.] - ETA: 0s - loss: 0.1048 - acc: 0
.9659Epoch 1/100
  1/163 [..............................] - ETA: 44s - loss: 4.2677 - acc:
0.5000
Epoch 00074: saving model to /content/data/model/weights.epoch_74.hdf5
163/163 [==============================] - 92s 564ms/step - loss: 0.1044 -
acc: 0.9659 - val_loss: 4.2677 - val_acc: 0.5000
Epoch 75/100
162/163 [============================>.] - ETA: 0s - loss: 0.1018 - acc: 0
.9678Epoch 1/100
  1/163 [..............................] - ETA: 41s - loss: 4.9657 - acc:
0.5000
Epoch 00075: saving model to /content/data/model/weights.epoch_75.hdf5
163/163 [==============================] - 91s 561ms/step - loss: 0.1013 -
acc: 0.9680 - val_loss: 4.9657 - val_acc: 0.5000
Epoch 76/100
162/163 [============================>.] - ETA: 0s - loss: 0.0955 - acc: 0
.9728Epoch 1/100
```

```
  1/163 [..............................] - ETA: 43s - loss: 4.4976 - acc: 
0.5000
Epoch 00076: saving model to /content/data/model/weights.epoch_76.hdf5
163/163 [==============================] - 92s 563ms/step - loss: 0.0949 - 
acc: 0.9730 - val_loss: 4.4976 - val_acc: 0.5000
Epoch 77/100
162/163 [============================>.] - ETA: 0s - loss: 0.1013 - acc: 0
.9668Epoch 1/100
  1/163 [..............................] - ETA: 42s - loss: 4.6798 - acc: 
0.5000
Epoch 00077: saving model to /content/data/model/weights.epoch_77.hdf5
163/163 [==============================] - 92s 564ms/step - loss: 0.1007 - 
acc: 0.9670 - val_loss: 4.6798 - val_acc: 0.5000
Epoch 78/100
162/163 [============================>.] - ETA: 0s - loss: 0.0976 - acc: 0
.9678Epoch 1/100
  1/163 [..............................] - ETA: 43s - loss: 4.9274 - acc: 
0.5000
Epoch 00078: saving model to /content/data/model/weights.epoch_78.hdf5
163/163 [==============================] - 92s 564ms/step - loss: 0.0980 - 
acc: 0.9674 - val_loss: 4.9274 - val_acc: 0.5000
Epoch 79/100
162/163 [============================>.] - ETA: 0s - loss: 0.1084 - acc: 0
.9699Epoch 1/100
  1/163 [..............................] - ETA: 44s - loss: 3.4269 - acc: 
0.5625
Epoch 00079: saving model to /content/data/model/weights.epoch_79.hdf5
163/163 [==============================] - 91s 561ms/step - loss: 0.1079 - 
acc: 0.9701 - val_loss: 3.4269 - val_acc: 0.5625
Epoch 80/100
162/163 [============================>.] - ETA: 0s - loss: 0.0975 - acc: 0
.9703Epoch 1/100
  1/163 [..............................] - ETA: 43s - loss: 4.4476 - acc: 
0.5000
Epoch 00080: saving model to /content/data/model/weights.epoch_80.hdf5
163/163 [==============================] - 92s 565ms/step - loss: 0.0974 - 
acc: 0.9703 - val_loss: 4.4476 - val_acc: 0.5000
Epoch 81/100
162/163 [============================>.] - ETA: 0s - loss: 0.1075 - acc: 0
.9688Epoch 1/100
  1/163 [..............................] - ETA: 41s - loss: 2.9928 - acc: 
0.5625
Epoch 00081: saving model to /content/data/model/weights.epoch_81.hdf5
163/163 [==============================] - 92s 565ms/step - loss: 0.1082 - 
acc: 0.9686 - val_loss: 2.9928 - val_acc: 0.5625
Epoch 82/100
162/163 [============================>.] - ETA: 0s - loss: 0.1036 - acc: 0
.9711Epoch 1/100
  1/163 [..............................] - ETA: 44s - loss: 4.9711 - acc: 
0.5000
Epoch 00082: saving model to /content/data/model/weights.epoch_82.hdf5
163/163 [==============================] - 92s 565ms/step - loss: 0.1030 - 
acc: 0.9712 - val_loss: 4.9711 - val_acc: 0.5000
Epoch 83/100
```

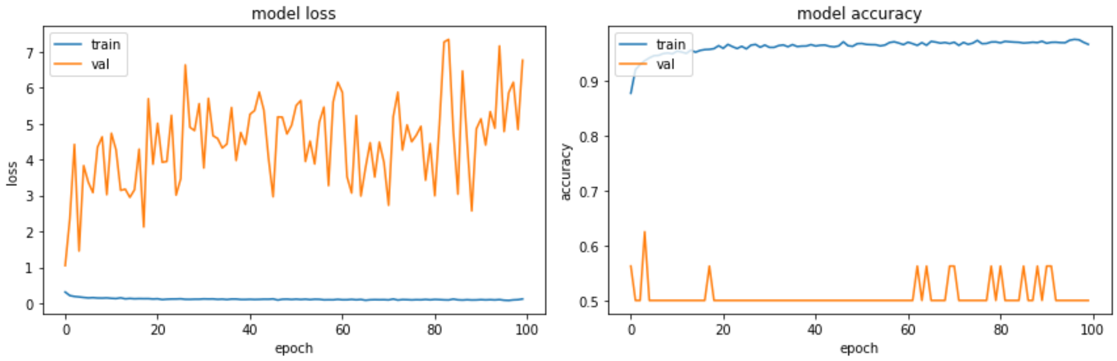
```
162/163 [============================>.] - ETA: 0s - loss: 0.0968 - acc: 0
.9703Epoch 1/100
  1/163 [..............................] - ETA: 45s - loss: 7.2739 - acc:
0.5000
Epoch 00083: saving model to /content/data/model/weights.epoch_83.hdf5
163/163 [==============================] - 92s 562ms/step - loss: 0.0962 -
acc: 0.9705 - val_loss: 7.2739 - val_acc: 0.5000
Epoch 84/100
162/163 [============================>.] - ETA: 0s - loss: 0.0937 - acc: 0
.9697Epoch 1/100
  1/163 [..............................] - ETA: 42s - loss: 7.3478 - acc:
0.5000
Epoch 00084: saving model to /content/data/model/weights.epoch_84.hdf5
163/163 [==============================] - 92s 566ms/step - loss: 0.0931 -
acc: 0.9699 - val_loss: 7.3478 - val_acc: 0.5000
Epoch 85/100
162/163 [============================>.] - ETA: 0s - loss: 0.1186 - acc: 0
.9695Epoch 1/100
  1/163 [..............................] - ETA: 43s - loss: 4.8109 - acc:
0.5000
Epoch 00085: saving model to /content/data/model/weights.epoch_85.hdf5
163/163 [==============================] - 92s 562ms/step - loss: 0.1181 -
acc: 0.9695 - val_loss: 4.8109 - val_acc: 0.5000
Epoch 86/100
162/163 [============================>.] - ETA: 0s - loss: 0.0973 - acc: 0
.9682Epoch 1/100
  1/163 [..............................] - ETA: 43s - loss: 3.0385 - acc:
0.5625
Epoch 00086: saving model to /content/data/model/weights.epoch_86.hdf5
163/163 [==============================] - 92s 562ms/step - loss: 0.0969 -
acc: 0.9682 - val_loss: 3.0385 - val_acc: 0.5625
Epoch 87/100
162/163 [============================>.] - ETA: 0s - loss: 0.0909 - acc: 0
.9691Epoch 1/100
  1/163 [..............................] - ETA: 43s - loss: 6.4692 - acc:
0.5000
Epoch 00087: saving model to /content/data/model/weights.epoch_87.hdf5
163/163 [==============================] - 92s 564ms/step - loss: 0.0911 -
acc: 0.9688 - val_loss: 6.4692 - val_acc: 0.5000
Epoch 88/100
162/163 [============================>.] - ETA: 0s - loss: 0.1000 - acc: 0
.9695Epoch 1/100
  1/163 [..............................] - ETA: 45s - loss: 4.4860 - acc:
0.5000
Epoch 00088: saving model to /content/data/model/weights.epoch_88.hdf5
163/163 [==============================] - 91s 560ms/step - loss: 0.0995 -
acc: 0.9697 - val_loss: 4.4860 - val_acc: 0.5000
Epoch 89/100
162/163 [============================>.] - ETA: 0s - loss: 0.0925 - acc: 0
.9689Epoch 1/100
  1/163 [..............................] - ETA: 43s - loss: 2.5723 - acc:
0.5625
Epoch 00089: saving model to /content/data/model/weights.epoch_89.hdf5
163/163 [==============================] - 92s 562ms/step - loss: 0.0922 -
```

```
acc: 0.9689 - val_loss: 2.5723 - val_acc: 0.5625
Epoch 90/100
162/163 [============================>.] - ETA: 0s - loss: 0.0942 - acc: 0
.9715Epoch 1/100
  1/163 [..............................] - ETA: 45s - loss: 4.8586 - acc:
0.5000
Epoch 00090: saving model to /content/data/model/weights.epoch_90.hdf5
163/163 [==============================] - 92s 563ms/step - loss: 0.0944 -
acc: 0.9714 - val_loss: 4.8586 - val_acc: 0.5000
Epoch 91/100
162/163 [============================>.] - ETA: 0s - loss: 0.1020 - acc: 0
.9678Epoch 1/100
  1/163 [..............................] - ETA: 43s - loss: 5.1361 - acc:
0.5625
Epoch 00091: saving model to /content/data/model/weights.epoch_91.hdf5
163/163 [==============================] - 93s 572ms/step - loss: 0.1020 -
acc: 0.9678 - val_loss: 5.1361 - val_acc: 0.5625
Epoch 92/100
162/163 [============================>.] - ETA: 0s - loss: 0.0958 - acc: 0
.9695Epoch 1/100
  1/163 [..............................] - ETA: 43s - loss: 4.4073 - acc:
0.5625
Epoch 00092: saving model to /content/data/model/weights.epoch_92.hdf5
163/163 [==============================] - 94s 577ms/step - loss: 0.0958 -
acc: 0.9695 - val_loss: 4.4073 - val_acc: 0.5625
Epoch 93/100
162/163 [============================>.] - ETA: 0s - loss: 0.1007 - acc: 0
.9697Epoch 1/100
  1/163 [..............................] - ETA: 44s - loss: 5.3362 - acc:
0.5000
Epoch 00093: saving model to /content/data/model/weights.epoch_93.hdf5
163/163 [==============================] - 95s 583ms/step - loss: 0.1008 -
acc: 0.9697 - val_loss: 5.3362 - val_acc: 0.5000
Epoch 94/100
162/163 [============================>.] - ETA: 0s - loss: 0.0951 - acc: 0
.9688Epoch 1/100
  1/163 [..............................] - ETA: 48s - loss: 4.8754 - acc:
0.5000
Epoch 00094: saving model to /content/data/model/weights.epoch_94.hdf5
163/163 [==============================] - 96s 591ms/step - loss: 0.0946 -
acc: 0.9689 - val_loss: 4.8754 - val_acc: 0.5000
Epoch 95/100
162/163 [============================>.] - ETA: 0s - loss: 0.1028 - acc: 0
.9693Epoch 1/100
  1/163 [..............................] - ETA: 37s - loss: 7.1666 - acc:
0.5000
Epoch 00095: saving model to /content/data/model/weights.epoch_95.hdf5
163/163 [==============================] - 97s 594ms/step - loss: 0.1038 -
acc: 0.9688 - val_loss: 7.1666 - val_acc: 0.5000
Epoch 96/100
162/163 [============================>.] - ETA: 0s - loss: 0.0866 - acc: 0
.9732Epoch 1/100
  1/163 [..............................] - ETA: 44s - loss: 4.7808 - acc:
0.5000
```

```
Epoch 00096: saving model to /content/data/model/weights.epoch_96.hdf5
163/163 [==============================] - 97s 598ms/step - loss: 0.0861 -
acc: 0.9734 - val_loss: 4.7808 - val_acc: 0.5000
Epoch 97/100
162/163 [============================>.] - ETA: 0s - loss: 0.0805 - acc: 0
.9749Epoch 1/100
  1/163 [..............................] - ETA: 46s - loss: 5.8630 - acc:
0.5000
Epoch 00097: saving model to /content/data/model/weights.epoch_97.hdf5
163/163 [==============================] - 99s 606ms/step - loss: 0.0802 -
acc: 0.9749 - val_loss: 5.8630 - val_acc: 0.5000
Epoch 98/100
162/163 [============================>.] - ETA: 0s - loss: 0.0929 - acc: 0
.9742Epoch 1/100
  1/163 [..............................] - ETA: 44s - loss: 6.1549 - acc:
0.5000
Epoch 00098: saving model to /content/data/model/weights.epoch_98.hdf5
163/163 [==============================] - 98s 599ms/step - loss: 0.0951 -
acc: 0.9741 - val_loss: 6.1549 - val_acc: 0.5000
Epoch 99/100
162/163 [============================>.] - ETA: 0s - loss: 0.1015 - acc: 0
.9695Epoch 1/100
  1/163 [..............................] - ETA: 46s - loss: 4.8395 - acc:
0.5000
Epoch 00099: saving model to /content/data/model/weights.epoch_99.hdf5
163/163 [==============================] - 100s 616ms/step - loss: 0.1012
- acc: 0.9695 - val_loss: 4.8395 - val_acc: 0.5000
Epoch 100/100
162/163 [============================>.] - ETA: 0s - loss: 0.1210 - acc: 0
.9659Epoch 1/100
  1/163 [..............................] - ETA: 50s - loss: 6.7680 - acc:
0.5000
Epoch 00100: saving model to /content/data/model/weights.epoch_100.hdf5
163/163 [==============================] - 101s 617ms/step - loss: 0.1208
- acc: 0.9659 - val_loss: 6.7680 - val_acc: 0.5000
Loading the best model
epoch: 1, val_loss: 1.0501724481582642, val_acc: 0.5625
20/20 [==============================] - 6s 305ms/step - loss: 1.0415 - ac
c: 0.6442
20/20 [==============================] - 10s 488ms/step
CONFUSION MATRIX ------------------
[[ 13 221]
 [  1 389]]

TEST METRICS ----------------------
Accuracy: 64.42307692307693%
Precision: 63.77049180327868%
Recall: 99.74358974358975%
F1-score: 77.8

TRAIN METRIC ----------------------
Train acc: 96.58742547035219%
```



model loss
train
val
loss
epoch
model accuracy
train
val
accuracy
epoch

png

9.12 Appendix L: InceptionResNetV2

```
from __future__ import absolute_import, division, print_function, unicode_
literals
import tensorflow as tf

# Extract dataset
import os
import tarfile

import keras_preprocessing
from keras_preprocessing.image import ImageDataGenerator # Data preprocess
ing and augmentation

import sklearn
import numpy as np
```

The default version of TensorFlow in Colab will soon switch to TensorFlow 2.x. We recommend you upgrade now or ensure your notebook will continue to use TensorFlow 1.x via the %tensorflow_version 1.x magic: more info.

```
print(tf.__version__)
```

```
1.15.0
```

```
# Make folder for chest xray data
!mkdir /content/data/

# Make directory to save weights
!mkdir /content/data/model

# Make directory to logs for Tensorboard
!mkdir /content/data/graph

# Download dataset
!wget --no-check-certificate \
    https://s3.eu-central-1.amazonaws.com/public.unit8.co/data/chest_xray.
tar.gz \
    -O /content/data/chest_xray.tar.gz

tar = tarfile.open("data/chest_xray.tar.gz")
tar.extractall(path='./data/')
os.remove('data/chest_xray.tar.gz')
```

```
--2019-11-10 06:30:51--  https://s3.eu-central-1.amazonaws.com/public.unit
8.co/data/chest_xray.tar.gz
Resolving s3.eu-central-1.amazonaws.com (s3.eu-central-1.amazonaws.com)...
52.219.72.147
Connecting to s3.eu-central-1.amazonaws.com (s3.eu-central-1.amazonaws.com
)|52.219.72.147|:443... connected.
HTTP request sent, awaiting response... 200 OK
Length: 1225393795 (1.1G) [application/x-gzip]
Saving to: ‘/content/data/chest_xray.tar.gz’
```

```
/content/data/chest 100%[===================>]   1.14G  21.5MB/s    in 57s

2019-11-10 06:31:49 (20.4 MB/s) - ‘/content/data/chest_xray.tar.gz’ saved
[1225393795/1225393795]
```

Change log: > training_datagen –> ImageDataGenerator

trainable layer –> All except base

InceptionResNetV2 model - base, flat, dense

Optimizer = RMSprop(learning_rate = 0.0001)

loss = categorical_crosscentropy

callback = [checkpoints]

epochs = 100

no class weight balancing

```
TRAINING_DIR = "/content/data/chest_xray/train"
VALIDATION_DIR = "/content/data/chest_xray/val"
TEST_DIR = "/content/data/chest_xray/test"

training_datagen = ImageDataGenerator(
    preprocessing_function=tf.keras.applications.vgg16.preprocess_input,
    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,
    # vertical_flip=True
    fill_mode='nearest'
)

validation_datagen = ImageDataGenerator(
    rescale = 1./255
)

test_datagen = ImageDataGenerator(
    rescale = 1./255
)

# Create training data batch
# TODO: Try grayscaling the image to see what will happen
train_generator = training_datagen.flow_from_directory(
    TRAINING_DIR,
    target_size=(150,150),
    class_mode='categorical'
)

validation_generator = validation_datagen.flow_from_directory(
    VALIDATION_DIR,
    target_size=(150,150),
```

```
    class_mode='categorical'
)

test_generator = test_datagen.flow_from_directory(
    TEST_DIR,
    target_size=(150,150),
    class_mode='categorical',
    shuffle=False
)

train_shape = train_generator.image_shape

tf.keras.backend.clear_session() # Destroys the current TF graph and creat
es a new one.

base_model = tf.keras.applications.inception_resnet_v2.InceptionResNetV2(w
eights='imagenet', include_top=False, input_shape=train_shape)

# Define the machine learning model
x = base_model.output
x = tf.keras.layers.Flatten()(x)
x = tf.keras.layers.Dense(2, 'softmax')(x)

model = tf.keras.Model(inputs=base_model.input, outputs=x)

# for layer in model.layers[0:20]:
#     layer.trainable = False

for layer in base_model.layers:
  layer.trainable = False

optimizer = tf.keras.optimizers.RMSprop(learning_rate=0.0001) # Lower lear
ning rate by x10

model.compile(loss='categorical_crossentropy',
              optimizer=optimizer,
              metrics=['accuracy'])

# Callbacks stuff
# Function to save the weights of the model after each epoch
checkpoint = tf.keras.callbacks.ModelCheckpoint(
    '/content/data/model/weights.epoch_{epoch:02d}.hdf5',
    monitor='val_accuracy',
    save_best_only=False,
    save_weights_only=False,
    mode='auto',
    verbose=1
)

# Function to stop training early if there's no improvement
early_stopping_monitor = tf.keras.callbacks.EarlyStopping(patience = 3, mo
nitor = "val_loss", mode="auto", verbose = 1)

lr_reduce = tf.keras.callbacks.ReduceLROnPlateau(monitor='val_loss', facto
```

```
r=0.3, patience=2, verbose=1, mode='max')

classweight = sklearn.utils.class_weight.compute_class_weight('balanced',
np.unique(train_generator.labels), train_generator.labels)
print(classweight)

batch_size = 32
epochs = 100

# Training process
history = model.fit_generator(
    generator=train_generator,
    # steps_per_epoch=train_generator.samples//batch_size,
    epochs=epochs,
    # callbacks=[early_stopping_monitor],
    callbacks=[checkpoint],
    # shuffle=True,
    validation_data=validation_generator,
    # validation_steps= validation_generator//batch_size, #no because it's
gonna be 0... if leave alone its len(generator) which is equal to 1.
    # class_weight=classweight,
    verbose = 1
)

# test_loss, test_acc = model.evaluate_generator(generator=test_generator,
verbose=1)

### Plot training
import matplotlib.pyplot as plt
def plot_learning_curves(history):
    plt.figure(figsize=(12,4))

    plt.subplot(1,2,1)
    plt.plot(history.history['loss'])
    plt.plot(history.history['val_loss'])
    plt.title('model loss')
    plt.ylabel('loss')
    plt.xlabel('epoch')
    plt.legend(['train', 'val'], loc='upper left')

    plt.subplot(1,2,2)
    plt.plot(history.history['acc'])
    plt.plot(history.history['val_acc'])
    plt.title('model accuracy')
    plt.ylabel('accuracy')
    plt.xlabel('epoch')
    plt.legend(['train', 'val'], loc='upper left')

    plt.tight_layout()

plot_learning_curves(history)

## Load best weight
idx = np.argmin(history.history['val_loss'])
```

```
model.load_weights("/content/data/model/weights.epoch_{:02d}.hdf5".format(
idx + 1))

print("Loading the best model")
print("epoch: {}, val_loss: {}, val_acc: {}".format(idx + 1, history.histo
ry['val_loss'][idx], history.history['val_acc'][idx]))

## Evaluate the model
test_loss, test_acc = model.evaluate_generator(generator=test_generator, v
erbose=1)

## Analytics
from sklearn.metrics import accuracy_score, confusion_matrix

test_generator.reset()
test_preds = model.predict_generator(test_generator, verbose=1)
test_preds = np.argmax(test_preds,axis=1)

acc = accuracy_score(test_generator.classes, test_preds)*100
cm = confusion_matrix(test_generator.classes, test_preds)
tn, fp, fn, tp = cm.ravel()

print('CONFUSION MATRIX ------------------')
print(cm)
# plot_confusion_matrix(cm, target_names=['NORMAL', 'PNEUMONIA'], normaliz
e=False)


print('\nTEST METRICS ----------------------')
precision = tp/(tp+fp)*100
recall = tp/(tp+fn)*100
print('Accuracy: {}%'.format(acc))
print('Precision: {}%'.format(precision))
print('Recall: {}%'.format(recall))
print('F1-score: {}'.format(2*precision*recall/(precision+recall)))

print('\nTRAIN METRIC ----------------------')
print('Train acc: {}%'.format(np.round((history.history['acc'][-1])*100, 1
4)))
```

```
Found 5216 images belonging to 2 classes.
Found 16 images belonging to 2 classes.
Found 624 images belonging to 2 classes.
WARNING:tensorflow:From /usr/local/lib/python3.6/dist-packages/tensorflow_
core/python/ops/resource_variable_ops.py:1630: calling BaseResourceVariabl
e.__init__ (from tensorflow.python.ops.resource_variable_ops) with constra
int is deprecated and will be removed in a future version.
Instructions for updating:
If using Keras pass *_constraint arguments to layers.
Downloading data from https://github.com/fchollet/deep-learning-models/rel
eases/download/v0.7/inception_resnet_v2_weights_tf_dim_ordering_tf_kernels
_notop.h5
219062272/219055592 [==============================] - 7s 0us/step
[1.9448173  0.67303226]
```

```
Epoch 1/100
162/163 [============================>.] - ETA: 0s - loss: 0.3660 - acc: 0
.8536Epoch 1/100
  1/163 [..............................] - ETA: 21:28 - loss: 2.1733 - acc
: 0.5000
Epoch 00001: saving model to /content/data/model/weights.epoch_01.hdf5
163/163 [==============================] - 250s 2s/step - loss: 0.3662 - a
cc: 0.8539 - val_loss: 2.1733 - val_acc: 0.5000
Epoch 2/100
162/163 [============================>.] - ETA: 0s - loss: 0.2467 - acc: 0
.9107Epoch 1/100
  1/163 [..............................] - ETA: 1:01 - loss: 3.1384 - acc:
0.5000
Epoch 00002: saving model to /content/data/model/weights.epoch_02.hdf5
163/163 [==============================] - 90s 551ms/step - loss: 0.2466 -
acc: 0.9107 - val_loss: 3.1384 - val_acc: 0.5000
Epoch 3/100
162/163 [============================>.] - ETA: 0s - loss: 0.2185 - acc: 0
.9211Epoch 1/100
  1/163 [..............................] - ETA: 1:02 - loss: 3.1438 - acc:
0.5000
Epoch 00003: saving model to /content/data/model/weights.epoch_03.hdf5
163/163 [==============================] - 94s 579ms/step - loss: 0.2189 -
acc: 0.9212 - val_loss: 3.1438 - val_acc: 0.5000
Epoch 4/100
162/163 [============================>.] - ETA: 0s - loss: 0.2046 - acc: 0
.9282Epoch 1/100
  1/163 [..............................] - ETA: 1:04 - loss: 2.3760 - acc:
0.5000
Epoch 00004: saving model to /content/data/model/weights.epoch_04.hdf5
163/163 [==============================] - 94s 579ms/step - loss: 0.2046 -
acc: 0.9283 - val_loss: 2.3760 - val_acc: 0.5000
Epoch 5/100
162/163 [============================>.] - ETA: 0s - loss: 0.1882 - acc: 0
.9342Epoch 1/100
  1/163 [..............................] - ETA: 1:08 - loss: 5.1627 - acc:
0.5000
Epoch 00005: saving model to /content/data/model/weights.epoch_05.hdf5
163/163 [==============================] - 94s 574ms/step - loss: 0.1874 -
acc: 0.9346 - val_loss: 5.1627 - val_acc: 0.5000
Epoch 6/100
162/163 [============================>.] - ETA: 0s - loss: 0.1709 - acc: 0
.9369Epoch 1/100
  1/163 [..............................] - ETA: 1:06 - loss: 4.6479 - acc:
0.5000
Epoch 00006: saving model to /content/data/model/weights.epoch_06.hdf5
163/163 [==============================] - 94s 575ms/step - loss: 0.1707 -
acc: 0.9367 - val_loss: 4.6479 - val_acc: 0.5000
Epoch 7/100
162/163 [============================>.] - ETA: 0s - loss: 0.1717 - acc: 0
.9410Epoch 1/100
  1/163 [..............................] - ETA: 1:00 - loss: 5.3248 - acc:
0.5000
Epoch 00007: saving model to /content/data/model/weights.epoch_07.hdf5
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163/163 [==============================] - 94s 578ms/step - loss: 0.1710 -
acc: 0.9413 - val_loss: 5.3248 - val_acc: 0.5000
Epoch 8/100
162/163 [============================>.] - ETA: 0s - loss: 0.1726 - acc: 0
.9375Epoch 1/100
  1/163 [..............................] - ETA: 1:05 - loss: 3.1112 - acc:
0.5000
Epoch 00008: saving model to /content/data/model/weights.epoch_08.hdf5
163/163 [==============================] - 94s 576ms/step - loss: 0.1720 -
acc: 0.9379 - val_loss: 3.1112 - val_acc: 0.5000
Epoch 9/100
162/163 [============================>.] - ETA: 0s - loss: 0.1678 - acc: 0
.9417Epoch 1/100
  1/163 [..............................] - ETA: 1:00 - loss: 4.5461 - acc:
0.5000
Epoch 00009: saving model to /content/data/model/weights.epoch_09.hdf5
163/163 [==============================] - 95s 581ms/step - loss: 0.1672 -
acc: 0.9419 - val_loss: 4.5461 - val_acc: 0.5000
Epoch 10/100
162/163 [============================>.] - ETA: 0s - loss: 0.1537 - acc: 0
.9439Epoch 1/100
  1/163 [..............................] - ETA: 1:08 - loss: 2.6268 - acc:
0.5000
Epoch 00010: saving model to /content/data/model/weights.epoch_10.hdf5
163/163 [==============================] - 95s 581ms/step - loss: 0.1535 -
acc: 0.9440 - val_loss: 2.6268 - val_acc: 0.5000
Epoch 11/100
162/163 [============================>.] - ETA: 0s - loss: 0.1524 - acc: 0
.9475Epoch 1/100
  1/163 [..............................] - ETA: 1:06 - loss: 6.3946 - acc:
0.5000
Epoch 00011: saving model to /content/data/model/weights.epoch_11.hdf5
163/163 [==============================] - 94s 579ms/step - loss: 0.1529 -
acc: 0.9473 - val_loss: 6.3946 - val_acc: 0.5000
Epoch 12/100
162/163 [============================>.] - ETA: 0s - loss: 0.1477 - acc: 0
.9483Epoch 1/100
  1/163 [..............................] - ETA: 1:07 - loss: 5.3360 - acc:
0.5000
Epoch 00012: saving model to /content/data/model/weights.epoch_12.hdf5
163/163 [==============================] - 95s 585ms/step - loss: 0.1473 -
acc: 0.9482 - val_loss: 5.3360 - val_acc: 0.5000
Epoch 13/100
162/163 [============================>.] - ETA: 0s - loss: 0.1452 - acc: 0
.9483Epoch 1/100
  1/163 [..............................] - ETA: 1:06 - loss: 4.5724 - acc:
0.5000
Epoch 00013: saving model to /content/data/model/weights.epoch_13.hdf5
163/163 [==============================] - 95s 581ms/step - loss: 0.1455 -
acc: 0.9480 - val_loss: 4.5724 - val_acc: 0.5000
Epoch 14/100
162/163 [============================>.] - ETA: 0s - loss: 0.1469 - acc: 0
.9524Epoch 1/100
  1/163 [..............................] - ETA: 1:07 - loss: 2.4982 - acc:
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0.5000
Epoch 00014: saving model to /content/data/model/weights.epoch_14.hdf5
163/163 [==============================] - 94s 579ms/step - loss: 0.1476 -
acc: 0.9521 - val_loss: 2.4982 - val_acc: 0.5000
Epoch 15/100
162/163 [============================>.] - ETA: 0s - loss: 0.1509 - acc: 0
.9485Epoch 1/100
  1/163 [..............................] - ETA: 1:04 - loss: 4.9143 - acc:
0.5000
Epoch 00015: saving model to /content/data/model/weights.epoch_15.hdf5
163/163 [==============================] - 94s 575ms/step - loss: 0.1511 -
acc: 0.9482 - val_loss: 4.9143 - val_acc: 0.5000
Epoch 16/100
162/163 [============================>.] - ETA: 0s - loss: 0.1472 - acc: 0
.9466Epoch 1/100
  1/163 [..............................] - ETA: 1:07 - loss: 4.2595 - acc:
0.5000
Epoch 00016: saving model to /content/data/model/weights.epoch_16.hdf5
163/163 [==============================] - 94s 579ms/step - loss: 0.1473 -
acc: 0.9465 - val_loss: 4.2595 - val_acc: 0.5000
Epoch 17/100
162/163 [============================>.] - ETA: 0s - loss: 0.1347 - acc: 0
.9524Epoch 1/100
  1/163 [..............................] - ETA: 1:06 - loss: 7.5473 - acc:
0.5000
Epoch 00017: saving model to /content/data/model/weights.epoch_17.hdf5
163/163 [==============================] - 94s 577ms/step - loss: 0.1348 -
acc: 0.9523 - val_loss: 7.5473 - val_acc: 0.5000
Epoch 18/100
162/163 [============================>.] - ETA: 0s - loss: 0.1438 - acc: 0
.9487Epoch 1/100
  1/163 [..............................] - ETA: 1:05 - loss: 6.0579 - acc:
0.5000
Epoch 00018: saving model to /content/data/model/weights.epoch_18.hdf5
163/163 [==============================] - 94s 575ms/step - loss: 0.1440 -
acc: 0.9482 - val_loss: 6.0579 - val_acc: 0.5000
Epoch 19/100
162/163 [============================>.] - ETA: 0s - loss: 0.1382 - acc: 0
.9512Epoch 1/100
  1/163 [..............................] - ETA: 1:07 - loss: 6.3253 - acc:
0.5000
Epoch 00019: saving model to /content/data/model/weights.epoch_19.hdf5
163/163 [==============================] - 95s 581ms/step - loss: 0.1379 -
acc: 0.9511 - val_loss: 6.3253 - val_acc: 0.5000
Epoch 20/100
162/163 [============================>.] - ETA: 0s - loss: 0.1396 - acc: 0
.9504Epoch 1/100
  1/163 [..............................] - ETA: 1:03 - loss: 4.4814 - acc:
0.5000
Epoch 00020: saving model to /content/data/model/weights.epoch_20.hdf5
163/163 [==============================] - 94s 577ms/step - loss: 0.1392 -
acc: 0.9507 - val_loss: 4.4814 - val_acc: 0.5000
Epoch 21/100
162/163 [============================>.] - ETA: 0s - loss: 0.1292 - acc: 0
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.9533Epoch 1/100
  1/163 [..............................] - ETA: 1:09 - loss: 7.8599 - acc: 
0.5000
Epoch 00021: saving model to /content/data/model/weights.epoch_21.hdf5
163/163 [==============================] - 94s 577ms/step - loss: 0.1293 - 
acc: 0.9530 - val_loss: 7.8599 - val_acc: 0.5000
Epoch 22/100
162/163 [============================>.] - ETA: 0s - loss: 0.1340 - acc: 0
.9533Epoch 1/100
  1/163 [..............................] - ETA: 1:05 - loss: 4.6502 - acc: 
0.5000
Epoch 00022: saving model to /content/data/model/weights.epoch_22.hdf5
163/163 [==============================] - 94s 576ms/step - loss: 0.1339 - 
acc: 0.9532 - val_loss: 4.6502 - val_acc: 0.5000
Epoch 23/100
162/163 [============================>.] - ETA: 0s - loss: 0.1314 - acc: 0
.9543Epoch 1/100
  1/163 [..............................] - ETA: 1:06 - loss: 4.3661 - acc: 
0.5000
Epoch 00023: saving model to /content/data/model/weights.epoch_23.hdf5
163/163 [==============================] - 94s 580ms/step - loss: 0.1318 - 
acc: 0.9542 - val_loss: 4.3661 - val_acc: 0.5000
Epoch 24/100
162/163 [============================>.] - ETA: 0s - loss: 0.1358 - acc: 0
.9549Epoch 1/100
  1/163 [..............................] - ETA: 1:07 - loss: 1.0469 - acc: 
0.5625
Epoch 00024: saving model to /content/data/model/weights.epoch_24.hdf5
163/163 [==============================] - 95s 582ms/step - loss: 0.1352 - 
acc: 0.9551 - val_loss: 1.0469 - val_acc: 0.5625
Epoch 25/100
162/163 [============================>.] - ETA: 0s - loss: 0.1368 - acc: 0
.9502Epoch 1/100
  1/163 [..............................] - ETA: 1:05 - loss: 1.6101 - acc: 
0.5000
Epoch 00025: saving model to /content/data/model/weights.epoch_25.hdf5
163/163 [==============================] - 94s 579ms/step - loss: 0.1366 - 
acc: 0.9503 - val_loss: 1.6101 - val_acc: 0.5000
Epoch 26/100
162/163 [============================>.] - ETA: 0s - loss: 0.1342 - acc: 0
.9531Epoch 1/100
  1/163 [..............................] - ETA: 1:06 - loss: 5.5799 - acc: 
0.5000
Epoch 00026: saving model to /content/data/model/weights.epoch_26.hdf5
163/163 [==============================] - 95s 582ms/step - loss: 0.1355 - 
acc: 0.9530 - val_loss: 5.5799 - val_acc: 0.5000
Epoch 27/100
162/163 [============================>.] - ETA: 0s - loss: 0.1352 - acc: 0
.9506Epoch 1/100
  1/163 [..............................] - ETA: 1:06 - loss: 6.0717 - acc: 
0.5000
Epoch 00027: saving model to /content/data/model/weights.epoch_27.hdf5
163/163 [==============================] - 94s 579ms/step - loss: 0.1351 - 
acc: 0.9505 - val_loss: 6.0717 - val_acc: 0.5000
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Epoch 28/100
162/163 [============================>.] - ETA: 0s - loss: 0.1234 - acc: 0
.9558Epoch 1/100
  1/163 [..............................] - ETA: 1:03 - loss: 6.7225 - acc:
0.5000
Epoch 00028: saving model to /content/data/model/weights.epoch_28.hdf5
163/163 [==============================] - 94s 574ms/step - loss: 0.1230 -
acc: 0.9559 - val_loss: 6.7225 - val_acc: 0.5000
Epoch 29/100
162/163 [============================>.] - ETA: 0s - loss: 0.1341 - acc: 0
.9502Epoch 1/100
  1/163 [..............................] - ETA: 1:06 - loss: 5.2360 - acc:
0.5000
Epoch 00029: saving model to /content/data/model/weights.epoch_29.hdf5
163/163 [==============================] - 95s 581ms/step - loss: 0.1338 -
acc: 0.9503 - val_loss: 5.2360 - val_acc: 0.5000
Epoch 30/100
162/163 [============================>.] - ETA: 0s - loss: 0.1323 - acc: 0
.9518Epoch 1/100
  1/163 [..............................] - ETA: 1:05 - loss: 6.8842 - acc:
0.5000
Epoch 00030: saving model to /content/data/model/weights.epoch_30.hdf5
163/163 [==============================] - 95s 581ms/step - loss: 0.1323 -
acc: 0.9517 - val_loss: 6.8842 - val_acc: 0.5000
Epoch 31/100
162/163 [============================>.] - ETA: 0s - loss: 0.1211 - acc: 0
.9568Epoch 1/100
  1/163 [..............................] - ETA: 1:09 - loss: 6.8019 - acc:
0.5000
Epoch 00031: saving model to /content/data/model/weights.epoch_31.hdf5
163/163 [==============================] - 96s 587ms/step - loss: 0.1208 -
acc: 0.9571 - val_loss: 6.8019 - val_acc: 0.5000
Epoch 32/100
162/163 [============================>.] - ETA: 0s - loss: 0.1314 - acc: 0
.9508Epoch 1/100
  1/163 [..............................] - ETA: 1:06 - loss: 7.6214 - acc:
0.5000
Epoch 00032: saving model to /content/data/model/weights.epoch_32.hdf5
163/163 [==============================] - 95s 585ms/step - loss: 0.1315 -
acc: 0.9507 - val_loss: 7.6214 - val_acc: 0.5000
Epoch 33/100
162/163 [============================>.] - ETA: 0s - loss: 0.1234 - acc: 0
.9562Epoch 1/100
  1/163 [..............................] - ETA: 1:06 - loss: 5.8043 - acc:
0.5000
Epoch 00033: saving model to /content/data/model/weights.epoch_33.hdf5
163/163 [==============================] - 95s 584ms/step - loss: 0.1231 -
acc: 0.9565 - val_loss: 5.8043 - val_acc: 0.5000
Epoch 34/100
162/163 [============================>.] - ETA: 0s - loss: 0.1240 - acc: 0
.9539Epoch 1/100
  1/163 [..............................] - ETA: 1:33 - loss: 3.0037 - acc:
0.5000
Epoch 00034: saving model to /content/data/model/weights.epoch_34.hdf5
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163/163 [==============================] - 95s 582ms/step - loss: 0.1239 -
acc: 0.9540 - val_loss: 3.0037 - val_acc: 0.5000
Epoch 35/100
162/163 [============================>.] - ETA: 0s - loss: 0.1231 - acc: 0
.9551Epoch 1/100
  1/163 [..............................] - ETA: 1:06 - loss: 4.5299 - acc:
0.5000
Epoch 00035: saving model to /content/data/model/weights.epoch_35.hdf5
163/163 [==============================] - 95s 581ms/step - loss: 0.1232 -
acc: 0.9551 - val_loss: 4.5299 - val_acc: 0.5000
Epoch 36/100
162/163 [============================>.] - ETA: 0s - loss: 0.1179 - acc: 0
.9562Epoch 1/100
  1/163 [..............................] - ETA: 1:05 - loss: 5.6313 - acc:
0.5000
Epoch 00036: saving model to /content/data/model/weights.epoch_36.hdf5
163/163 [==============================] - 95s 584ms/step - loss: 0.1187 -
acc: 0.9561 - val_loss: 5.6313 - val_acc: 0.5000
Epoch 37/100
162/163 [============================>.] - ETA: 0s - loss: 0.1288 - acc: 0
.9537Epoch 1/100
  1/163 [..............................] - ETA: 1:07 - loss: 3.3033 - acc:
0.5000
Epoch 00037: saving model to /content/data/model/weights.epoch_37.hdf5
163/163 [==============================] - 95s 585ms/step - loss: 0.1284 -
acc: 0.9538 - val_loss: 3.3033 - val_acc: 0.5000
Epoch 38/100
162/163 [============================>.] - ETA: 0s - loss: 0.1265 - acc: 0
.9539Epoch 1/100
  1/163 [..............................] - ETA: 1:06 - loss: 5.1963 - acc:
0.5000
Epoch 00038: saving model to /content/data/model/weights.epoch_38.hdf5
163/163 [==============================] - 95s 583ms/step - loss: 0.1259 -
acc: 0.9542 - val_loss: 5.1963 - val_acc: 0.5000
Epoch 39/100
162/163 [============================>.] - ETA: 0s - loss: 0.1260 - acc: 0
.9525Epoch 1/100
  1/163 [..............................] - ETA: 58s - loss: 5.1290 - acc:
0.5000
Epoch 00039: saving model to /content/data/model/weights.epoch_39.hdf5
163/163 [==============================] - 96s 587ms/step - loss: 0.1256 -
acc: 0.9528 - val_loss: 5.1290 - val_acc: 0.5000
Epoch 40/100
162/163 [============================>.] - ETA: 0s - loss: 0.1218 - acc: 0
.9552Epoch 1/100
  1/163 [..............................] - ETA: 1:07 - loss: 4.6793 - acc:
0.5000
Epoch 00040: saving model to /content/data/model/weights.epoch_40.hdf5
163/163 [==============================] - 95s 584ms/step - loss: 0.1215 -
acc: 0.9555 - val_loss: 4.6793 - val_acc: 0.5000
Epoch 41/100
162/163 [============================>.] - ETA: 0s - loss: 0.1254 - acc: 0
.9552Epoch 1/100
  1/163 [..............................] - ETA: 1:04 - loss: 2.8677 - acc:
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0.5000
Epoch 00041: saving model to /content/data/model/weights.epoch_41.hdf5
163/163 [==============================] - 95s 581ms/step - loss: 0.1251 -
acc: 0.9555 - val_loss: 2.8677 - val_acc: 0.5000
Epoch 42/100
162/163 [============================>.] - ETA: 0s - loss: 0.1264 - acc: 0
.9545Epoch 1/100
  1/163 [..............................] - ETA: 1:00 - loss: 5.2576 - acc:
0.5000
Epoch 00042: saving model to /content/data/model/weights.epoch_42.hdf5
163/163 [==============================] - 96s 586ms/step - loss: 0.1264 -
acc: 0.9544 - val_loss: 5.2576 - val_acc: 0.5000
Epoch 43/100
162/163 [============================>.] - ETA: 0s - loss: 0.1147 - acc: 0
.9587Epoch 1/100
  1/163 [..............................] - ETA: 1:04 - loss: 0.8690 - acc:
0.5625
Epoch 00043: saving model to /content/data/model/weights.epoch_43.hdf5
163/163 [==============================] - 95s 584ms/step - loss: 0.1154 -
acc: 0.9584 - val_loss: 0.8690 - val_acc: 0.5625
Epoch 44/100
162/163 [============================>.] - ETA: 0s - loss: 0.1233 - acc: 0
.9562Epoch 1/100
  1/163 [..............................] - ETA: 1:03 - loss: 3.0306 - acc:
0.5000
Epoch 00044: saving model to /content/data/model/weights.epoch_44.hdf5
163/163 [==============================] - 95s 582ms/step - loss: 0.1240 -
acc: 0.9559 - val_loss: 3.0306 - val_acc: 0.5000
Epoch 45/100
162/163 [============================>.] - ETA: 0s - loss: 0.1192 - acc: 0
.9578Epoch 1/100
  1/163 [..............................] - ETA: 1:05 - loss: 3.7795 - acc:
0.5000
Epoch 00045: saving model to /content/data/model/weights.epoch_45.hdf5
163/163 [==============================] - 96s 589ms/step - loss: 0.1188 -
acc: 0.9580 - val_loss: 3.7795 - val_acc: 0.5000
Epoch 46/100
162/163 [============================>.] - ETA: 0s - loss: 0.1216 - acc: 0
.9570Epoch 1/100
  1/163 [..............................] - ETA: 1:01 - loss: 3.9058 - acc:
0.5000
Epoch 00046: saving model to /content/data/model/weights.epoch_46.hdf5
163/163 [==============================] - 96s 586ms/step - loss: 0.1211 -
acc: 0.9571 - val_loss: 3.9058 - val_acc: 0.5000
Epoch 47/100
162/163 [============================>.] - ETA: 0s - loss: 0.1229 - acc: 0
.9568Epoch 1/100
  1/163 [..............................] - ETA: 1:05 - loss: 2.9049 - acc:
0.5000
Epoch 00047: saving model to /content/data/model/weights.epoch_47.hdf5
163/163 [==============================] - 95s 585ms/step - loss: 0.1225 -
acc: 0.9571 - val_loss: 2.9049 - val_acc: 0.5000
Epoch 48/100
162/163 [============================>.] - ETA: 0s - loss: 0.1140 - acc: 0
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.9593Epoch 1/100
  1/163 [..............................] - ETA: 1:10 - loss: 8.4007 - acc:
0.5000
Epoch 00048: saving model to /content/data/model/weights.epoch_48.hdf5
163/163 [==============================] - 94s 579ms/step - loss: 0.1138 -
acc: 0.9594 - val_loss: 8.4007 - val_acc: 0.5000
Epoch 49/100
162/163 [============================>.] - ETA: 0s - loss: 0.1193 - acc: 0
.9551Epoch 1/100
  1/163 [..............................] - ETA: 1:02 - loss: 5.1812 - acc:
0.5000
Epoch 00049: saving model to /content/data/model/weights.epoch_49.hdf5
163/163 [==============================] - 95s 584ms/step - loss: 0.1192 -
acc: 0.9551 - val_loss: 5.1812 - val_acc: 0.5000
Epoch 50/100
162/163 [============================>.] - ETA: 0s - loss: 0.1189 - acc: 0
.9551Epoch 1/100
  1/163 [..............................] - ETA: 1:06 - loss: 3.5493 - acc:
0.5000
Epoch 00050: saving model to /content/data/model/weights.epoch_50.hdf5
163/163 [==============================] - 94s 578ms/step - loss: 0.1190 -
acc: 0.9549 - val_loss: 3.5493 - val_acc: 0.5000
Epoch 51/100
162/163 [============================>.] - ETA: 0s - loss: 0.1079 - acc: 0
.9605Epoch 1/100
  1/163 [..............................] - ETA: 59s - loss: 2.4951 - acc:
0.5000
Epoch 00051: saving model to /content/data/model/weights.epoch_51.hdf5
163/163 [==============================] - 95s 585ms/step - loss: 0.1076 -
acc: 0.9607 - val_loss: 2.4951 - val_acc: 0.5000
Epoch 52/100
162/163 [============================>.] - ETA: 0s - loss: 0.1260 - acc: 0
.9552Epoch 1/100
  1/163 [..............................] - ETA: 1:05 - loss: 2.7216 - acc:
0.5000
Epoch 00052: saving model to /content/data/model/weights.epoch_52.hdf5
163/163 [==============================] - 96s 588ms/step - loss: 0.1256 -
acc: 0.9553 - val_loss: 2.7216 - val_acc: 0.5000
Epoch 53/100
162/163 [============================>.] - ETA: 0s - loss: 0.1193 - acc: 0
.9551Epoch 1/100
  1/163 [..............................] - ETA: 1:06 - loss: 2.9159 - acc:
0.5000
Epoch 00053: saving model to /content/data/model/weights.epoch_53.hdf5
163/163 [==============================] - 96s 587ms/step - loss: 0.1190 -
acc: 0.9551 - val_loss: 2.9159 - val_acc: 0.5000
Epoch 54/100
162/163 [============================>.] - ETA: 0s - loss: 0.1165 - acc: 0
.9570Epoch 1/100
  1/163 [..............................] - ETA: 58s - loss: 5.6651 - acc:
0.5000
Epoch 00054: saving model to /content/data/model/weights.epoch_54.hdf5
163/163 [==============================] - 96s 587ms/step - loss: 0.1164 -
acc: 0.9571 - val_loss: 5.6651 - val_acc: 0.5000
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Epoch 55/100
162/163 [============================>.] - ETA: 0s - loss: 0.1152 - acc: 0
.9599Epoch 1/100
  1/163 [..............................] - ETA: 1:06 - loss: 5.4586 - acc:
0.5000
Epoch 00055: saving model to /content/data/model/weights.epoch_55.hdf5
163/163 [==============================] - 95s 583ms/step - loss: 0.1153 -
acc: 0.9599 - val_loss: 5.4586 - val_acc: 0.5000
Epoch 56/100
162/163 [============================>.] - ETA: 0s - loss: 0.1160 - acc: 0
.9589Epoch 1/100
  1/163 [..............................] - ETA: 1:07 - loss: 0.8660 - acc:
0.6875
Epoch 00056: saving model to /content/data/model/weights.epoch_56.hdf5
163/163 [==============================] - 95s 582ms/step - loss: 0.1169 -
acc: 0.9588 - val_loss: 0.8660 - val_acc: 0.6875
Epoch 57/100
162/163 [============================>.] - ETA: 0s - loss: 0.1121 - acc: 0
.9560Epoch 1/100
  1/163 [..............................] - ETA: 1:06 - loss: 5.6143 - acc:
0.5000
Epoch 00057: saving model to /content/data/model/weights.epoch_57.hdf5
163/163 [==============================] - 95s 584ms/step - loss: 0.1118 -
acc: 0.9561 - val_loss: 5.6143 - val_acc: 0.5000
Epoch 58/100
162/163 [============================>.] - ETA: 0s - loss: 0.1192 - acc: 0
.9593Epoch 1/100
  1/163 [..............................] - ETA: 59s - loss: 4.0012 - acc:
0.5000
Epoch 00058: saving model to /content/data/model/weights.epoch_58.hdf5
163/163 [==============================] - 94s 578ms/step - loss: 0.1197 -
acc: 0.9590 - val_loss: 4.0012 - val_acc: 0.5000
Epoch 59/100
162/163 [============================>.] - ETA: 0s - loss: 0.1183 - acc: 0
.9568Epoch 1/100
  1/163 [..............................] - ETA: 1:02 - loss: 5.3796 - acc:
0.5000
Epoch 00059: saving model to /content/data/model/weights.epoch_59.hdf5
163/163 [==============================] - 95s 583ms/step - loss: 0.1184 -
acc: 0.9567 - val_loss: 5.3796 - val_acc: 0.5000
Epoch 60/100
162/163 [============================>.] - ETA: 0s - loss: 0.1145 - acc: 0
.9593Epoch 1/100
  1/163 [..............................] - ETA: 59s - loss: 5.0764 - acc:
0.5000
Epoch 00060: saving model to /content/data/model/weights.epoch_60.hdf5
163/163 [==============================] - 95s 583ms/step - loss: 0.1147 -
acc: 0.9594 - val_loss: 5.0764 - val_acc: 0.5000
Epoch 61/100
162/163 [============================>.] - ETA: 0s - loss: 0.1089 - acc: 0
.9608Epoch 1/100
  1/163 [..............................] - ETA: 59s - loss: 4.3240 - acc:
0.5000
Epoch 00061: saving model to /content/data/model/weights.epoch_61.hdf5
```

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163/163 [==============================] - 95s 583ms/step - loss: 0.1087 -
acc: 0.9607 - val_loss: 4.3240 - val_acc: 0.5000
Epoch 62/100
162/163 [============================>.] - ETA: 0s - loss: 0.1089 - acc: 0
.9595Epoch 1/100
  1/163 [..............................] - ETA: 1:06 - loss: 4.5413 - acc:
0.5000
Epoch 00062: saving model to /content/data/model/weights.epoch_62.hdf5
163/163 [==============================] - 95s 585ms/step - loss: 0.1090 -
acc: 0.9595 - val_loss: 4.5413 - val_acc: 0.5000
Epoch 63/100
162/163 [============================>.] - ETA: 0s - loss: 0.1174 - acc: 0
.9593Epoch 1/100
  1/163 [..............................] - ETA: 1:03 - loss: 6.4794 - acc:
0.5000
Epoch 00063: saving model to /content/data/model/weights.epoch_63.hdf5
163/163 [==============================] - 95s 583ms/step - loss: 0.1171 -
acc: 0.9595 - val_loss: 6.4794 - val_acc: 0.5000
Epoch 64/100
162/163 [============================>.] - ETA: 0s - loss: 0.1194 - acc: 0
.9599Epoch 1/100
  1/163 [..............................] - ETA: 1:05 - loss: 8.0238 - acc:
0.5000
Epoch 00064: saving model to /content/data/model/weights.epoch_64.hdf5
163/163 [==============================] - 95s 583ms/step - loss: 0.1205 -
acc: 0.9595 - val_loss: 8.0238 - val_acc: 0.5000
Epoch 65/100
162/163 [============================>.] - ETA: 0s - loss: 0.1114 - acc: 0
.9599Epoch 1/100
  1/163 [..............................] - ETA: 1:08 - loss: 3.6245 - acc:
0.5000
Epoch 00065: saving model to /content/data/model/weights.epoch_65.hdf5
163/163 [==============================] - 95s 584ms/step - loss: 0.1111 -
acc: 0.9601 - val_loss: 3.6245 - val_acc: 0.5000
Epoch 66/100
162/163 [============================>.] - ETA: 0s - loss: 0.1222 - acc: 0
.9576Epoch 1/100
  1/163 [..............................] - ETA: 1:04 - loss: 3.9132 - acc:
0.5000
Epoch 00066: saving model to /content/data/model/weights.epoch_66.hdf5
163/163 [==============================] - 95s 580ms/step - loss: 0.1218 -
acc: 0.9576 - val_loss: 3.9132 - val_acc: 0.5000
Epoch 67/100
162/163 [============================>.] - ETA: 0s - loss: 0.1147 - acc: 0
.9597Epoch 1/100
  1/163 [..............................] - ETA: 1:05 - loss: 1.7874 - acc:
0.5625
Epoch 00067: saving model to /content/data/model/weights.epoch_67.hdf5
163/163 [==============================] - 95s 580ms/step - loss: 0.1149 -
acc: 0.9594 - val_loss: 1.7874 - val_acc: 0.5625
Epoch 68/100
162/163 [============================>.] - ETA: 0s - loss: 0.1115 - acc: 0
.9593Epoch 1/100
  1/163 [..............................] - ETA: 1:08 - loss: 5.6390 - acc:
```

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0.5000
Epoch 00068: saving model to /content/data/model/weights.epoch_68.hdf5
163/163 [==============================] - 95s 583ms/step - loss: 0.1113 -
acc: 0.9594 - val_loss: 5.6390 - val_acc: 0.5000
Epoch 69/100
162/163 [============================>.] - ETA: 0s - loss: 0.1127 - acc: 0
.9601Epoch 1/100
  1/163 [..............................] - ETA: 1:03 - loss: 7.6957 - acc:
0.5000
Epoch 00069: saving model to /content/data/model/weights.epoch_69.hdf5
163/163 [==============================] - 95s 585ms/step - loss: 0.1124 -
acc: 0.9601 - val_loss: 7.6957 - val_acc: 0.5000
Epoch 70/100
162/163 [============================>.] - ETA: 0s - loss: 0.1163 - acc: 0
.9566Epoch 1/100
  1/163 [..............................] - ETA: 58s - loss: 3.6260 - acc:
0.5000
Epoch 00070: saving model to /content/data/model/weights.epoch_70.hdf5
163/163 [==============================] - 96s 587ms/step - loss: 0.1161 -
acc: 0.9567 - val_loss: 3.6260 - val_acc: 0.5000
Epoch 71/100
162/163 [============================>.] - ETA: 0s - loss: 0.1262 - acc: 0
.9541Epoch 1/100
  1/163 [..............................] - ETA: 1:05 - loss: 6.4404 - acc:
0.5000
Epoch 00071: saving model to /content/data/model/weights.epoch_71.hdf5
163/163 [==============================] - 96s 588ms/step - loss: 0.1267 -
acc: 0.9538 - val_loss: 6.4404 - val_acc: 0.5000
Epoch 72/100
162/163 [============================>.] - ETA: 0s - loss: 0.1096 - acc: 0
.9593Epoch 1/100
  1/163 [..............................] - ETA: 1:03 - loss: 5.7549 - acc:
0.5000
Epoch 00072: saving model to /content/data/model/weights.epoch_72.hdf5
163/163 [==============================] - 95s 586ms/step - loss: 0.1101 -
acc: 0.9594 - val_loss: 5.7549 - val_acc: 0.5000
Epoch 73/100
162/163 [============================>.] - ETA: 0s - loss: 0.1042 - acc: 0
.9622Epoch 1/100
  1/163 [..............................] - ETA: 1:06 - loss: 4.4353 - acc:
0.5000
Epoch 00073: saving model to /content/data/model/weights.epoch_73.hdf5
163/163 [==============================] - 96s 589ms/step - loss: 0.1040 -
acc: 0.9622 - val_loss: 4.4353 - val_acc: 0.5000
Epoch 74/100
162/163 [============================>.] - ETA: 0s - loss: 0.1175 - acc: 0
.9601Epoch 1/100
  1/163 [..............................] - ETA: 1:06 - loss: 4.1697 - acc:
0.5000
Epoch 00074: saving model to /content/data/model/weights.epoch_74.hdf5
163/163 [==============================] - 96s 588ms/step - loss: 0.1172 -
acc: 0.9601 - val_loss: 4.1697 - val_acc: 0.5000
Epoch 75/100
162/163 [============================>.] - ETA: 0s - loss: 0.1216 - acc: 0
```

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.9564Epoch 1/100
  1/163 [..............................] - ETA: 1:03 - loss: 6.1661 - acc: 
0.5000
Epoch 00075: saving model to /content/data/model/weights.epoch_75.hdf5
163/163 [==============================] - 96s 590ms/step - loss: 0.1213 - 
acc: 0.9565 - val_loss: 6.1661 - val_acc: 0.5000
Epoch 76/100
162/163 [============================>.] - ETA: 0s - loss: 0.1102 - acc: 0
.9581Epoch 1/100
  1/163 [..............................] - ETA: 1:06 - loss: 5.2231 - acc: 
0.5000
Epoch 00076: saving model to /content/data/model/weights.epoch_76.hdf5
163/163 [==============================] - 96s 587ms/step - loss: 0.1100 - 
acc: 0.9582 - val_loss: 5.2231 - val_acc: 0.5000
Epoch 77/100
162/163 [============================>.] - ETA: 0s - loss: 0.1052 - acc: 0
.9628Epoch 1/100
  1/163 [..............................] - ETA: 1:04 - loss: 3.6278 - acc: 
0.5000
Epoch 00077: saving model to /content/data/model/weights.epoch_77.hdf5
163/163 [==============================] - 96s 587ms/step - loss: 0.1065 - 
acc: 0.9622 - val_loss: 3.6278 - val_acc: 0.5000
Epoch 78/100
162/163 [============================>.] - ETA: 0s - loss: 0.1085 - acc: 0
.9618Epoch 1/100
  1/163 [..............................] - ETA: 1:07 - loss: 6.8788 - acc: 
0.5000
Epoch 00078: saving model to /content/data/model/weights.epoch_78.hdf5
163/163 [==============================] - 96s 592ms/step - loss: 0.1093 - 
acc: 0.9615 - val_loss: 6.8788 - val_acc: 0.5000
Epoch 79/100
162/163 [============================>.] - ETA: 0s - loss: 0.1123 - acc: 0
.9601Epoch 1/100
  1/163 [..............................] - ETA: 1:01 - loss: 6.4336 - acc: 
0.5000
Epoch 00079: saving model to /content/data/model/weights.epoch_79.hdf5
163/163 [==============================] - 96s 591ms/step - loss: 0.1122 - 
acc: 0.9601 - val_loss: 6.4336 - val_acc: 0.5000
Epoch 80/100
162/163 [============================>.] - ETA: 0s - loss: 0.1137 - acc: 0
.9589Epoch 1/100
  1/163 [..............................] - ETA: 1:06 - loss: 5.3855 - acc: 
0.5000
Epoch 00080: saving model to /content/data/model/weights.epoch_80.hdf5
163/163 [==============================] - 96s 587ms/step - loss: 0.1139 - 
acc: 0.9588 - val_loss: 5.3855 - val_acc: 0.5000
Epoch 81/100
162/163 [============================>.] - ETA: 0s - loss: 0.1064 - acc: 0
.9620Epoch 1/100
  1/163 [..............................] - ETA: 1:04 - loss: 6.2654 - acc: 
0.5000
Epoch 00081: saving model to /content/data/model/weights.epoch_81.hdf5
163/163 [==============================] - 95s 585ms/step - loss: 0.1060 - 
acc: 0.9622 - val_loss: 6.2654 - val_acc: 0.5000
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Epoch 82/100
162/163 [============================>.] - ETA: 0s - loss: 0.1029 - acc: 0
.9616Epoch 1/100
  1/163 [..............................] - ETA: 1:05 - loss: 6.9763 - acc:
0.5000
Epoch 00082: saving model to /content/data/model/weights.epoch_82.hdf5
163/163 [==============================] - 95s 585ms/step - loss: 0.1036 -
acc: 0.9613 - val_loss: 6.9763 - val_acc: 0.5000
Epoch 83/100
162/163 [============================>.] - ETA: 0s - loss: 0.1113 - acc: 0
.9585Epoch 1/100
  1/163 [..............................] - ETA: 1:04 - loss: 6.8694 - acc:
0.5000
Epoch 00083: saving model to /content/data/model/weights.epoch_83.hdf5
163/163 [==============================] - 95s 585ms/step - loss: 0.1109 -
acc: 0.9588 - val_loss: 6.8694 - val_acc: 0.5000
Epoch 84/100
162/163 [============================>.] - ETA: 0s - loss: 0.1141 - acc: 0
.9585Epoch 1/100
  1/163 [..............................] - ETA: 1:07 - loss: 5.7299 - acc:
0.5000
Epoch 00084: saving model to /content/data/model/weights.epoch_84.hdf5
163/163 [==============================] - 96s 587ms/step - loss: 0.1137 -
acc: 0.9588 - val_loss: 5.7299 - val_acc: 0.5000
Epoch 85/100
162/163 [============================>.] - ETA: 0s - loss: 0.1113 - acc: 0
.9614Epoch 1/100
  1/163 [..............................] - ETA: 1:06 - loss: 5.8954 - acc:
0.5000
Epoch 00085: saving model to /content/data/model/weights.epoch_85.hdf5
163/163 [==============================] - 95s 584ms/step - loss: 0.1113 -
acc: 0.9615 - val_loss: 5.8954 - val_acc: 0.5000
Epoch 86/100
162/163 [============================>.] - ETA: 0s - loss: 0.1134 - acc: 0
.9597Epoch 1/100
  1/163 [..............................] - ETA: 1:04 - loss: 6.3760 - acc:
0.5000
Epoch 00086: saving model to /content/data/model/weights.epoch_86.hdf5
163/163 [==============================] - 95s 585ms/step - loss: 0.1133 -
acc: 0.9597 - val_loss: 6.3760 - val_acc: 0.5000
Epoch 87/100
162/163 [============================>.] - ETA: 0s - loss: 0.1104 - acc: 0
.9620Epoch 1/100
  1/163 [..............................] - ETA: 1:06 - loss: 7.4921 - acc:
0.5000
Epoch 00087: saving model to /content/data/model/weights.epoch_87.hdf5
163/163 [==============================] - 95s 582ms/step - loss: 0.1112 -
acc: 0.9618 - val_loss: 7.4921 - val_acc: 0.5000
Epoch 88/100
162/163 [============================>.] - ETA: 0s - loss: 0.1106 - acc: 0
.9618Epoch 1/100
  1/163 [..............................] - ETA: 1:05 - loss: 5.9260 - acc:
0.5000
Epoch 00088: saving model to /content/data/model/weights.epoch_88.hdf5
```

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163/163 [==============================] - 95s 586ms/step - loss: 0.1105 -
acc: 0.9617 - val_loss: 5.9260 - val_acc: 0.5000
Epoch 89/100
162/163 [============================>.] - ETA: 0s - loss: 0.1203 - acc: 0
.9579Epoch 1/100
  1/163 [..............................] - ETA: 1:09 - loss: 7.1543 - acc:
0.5000
Epoch 00089: saving model to /content/data/model/weights.epoch_89.hdf5
163/163 [==============================] - 95s 584ms/step - loss: 0.1200 -
acc: 0.9580 - val_loss: 7.1543 - val_acc: 0.5000
Epoch 90/100
162/163 [============================>.] - ETA: 0s - loss: 0.1158 - acc: 0
.9581Epoch 1/100
  1/163 [..............................] - ETA: 1:06 - loss: 3.5203 - acc:
0.5000
Epoch 00090: saving model to /content/data/model/weights.epoch_90.hdf5
163/163 [==============================] - 95s 584ms/step - loss: 0.1157 -
acc: 0.9580 - val_loss: 3.5203 - val_acc: 0.5000
Epoch 91/100
162/163 [============================>.] - ETA: 0s - loss: 0.1065 - acc: 0
.9637Epoch 1/100
  1/163 [..............................] - ETA: 1:04 - loss: 7.0161 - acc:
0.5000
Epoch 00091: saving model to /content/data/model/weights.epoch_91.hdf5
163/163 [==============================] - 96s 589ms/step - loss: 0.1062 -
acc: 0.9638 - val_loss: 7.0161 - val_acc: 0.5000
Epoch 92/100
162/163 [============================>.] - ETA: 0s - loss: 0.1140 - acc: 0
.9593Epoch 1/100
  1/163 [..............................] - ETA: 1:06 - loss: 5.8336 - acc:
0.5000
Epoch 00092: saving model to /content/data/model/weights.epoch_92.hdf5
163/163 [==============================] - 96s 589ms/step - loss: 0.1138 -
acc: 0.9594 - val_loss: 5.8336 - val_acc: 0.5000
Epoch 93/100
162/163 [============================>.] - ETA: 0s - loss: 0.1084 - acc: 0
.9581Epoch 1/100
  1/163 [..............................] - ETA: 1:06 - loss: 4.9953 - acc:
0.5000
Epoch 00093: saving model to /content/data/model/weights.epoch_93.hdf5
163/163 [==============================] - 96s 587ms/step - loss: 0.1083 -
acc: 0.9582 - val_loss: 4.9953 - val_acc: 0.5000
Epoch 94/100
162/163 [============================>.] - ETA: 0s - loss: 0.1099 - acc: 0
.9606Epoch 1/100
  1/163 [..............................] - ETA: 1:01 - loss: 5.8071 - acc:
0.5000
Epoch 00094: saving model to /content/data/model/weights.epoch_94.hdf5
163/163 [==============================] - 96s 589ms/step - loss: 0.1105 -
acc: 0.9605 - val_loss: 5.8071 - val_acc: 0.5000
Epoch 95/100
162/163 [============================>.] - ETA: 0s - loss: 0.1095 - acc: 0
.9583Epoch 1/100
  1/163 [..............................] - ETA: 1:06 - loss: 5.0207 - acc:
```

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0.5000
Epoch 00095: saving model to /content/data/model/weights.epoch_95.hdf5
163/163 [==============================] - 95s 586ms/step - loss: 0.1091 -
acc: 0.9586 - val_loss: 5.0207 - val_acc: 0.5000
Epoch 96/100
162/163 [============================>.] - ETA: 0s - loss: 0.1094 - acc: 0
.9616Epoch 1/100
  1/163 [..............................] - ETA: 1:02 - loss: 5.6921 - acc:
0.5000
Epoch 00096: saving model to /content/data/model/weights.epoch_96.hdf5
163/163 [==============================] - 95s 585ms/step - loss: 0.1090 -
acc: 0.9617 - val_loss: 5.6921 - val_acc: 0.5000
Epoch 97/100
162/163 [============================>.] - ETA: 0s - loss: 0.1058 - acc: 0
.9608Epoch 1/100
  1/163 [..............................] - ETA: 1:05 - loss: 7.2704 - acc:
0.5000
Epoch 00097: saving model to /content/data/model/weights.epoch_97.hdf5
163/163 [==============================] - 96s 590ms/step - loss: 0.1065 -
acc: 0.9607 - val_loss: 7.2704 - val_acc: 0.5000
Epoch 98/100
162/163 [============================>.] - ETA: 0s - loss: 0.1090 - acc: 0
.9616Epoch 1/100
  1/163 [..............................] - ETA: 1:04 - loss: 5.4627 - acc:
0.5000
Epoch 00098: saving model to /content/data/model/weights.epoch_98.hdf5
163/163 [==============================] - 95s 585ms/step - loss: 0.1088 -
acc: 0.9617 - val_loss: 5.4627 - val_acc: 0.5000
Epoch 99/100
162/163 [============================>.] - ETA: 0s - loss: 0.0983 - acc: 0
.9660Epoch 1/100
  1/163 [..............................] - ETA: 1:07 - loss: 3.8404 - acc:
0.5000
Epoch 00099: saving model to /content/data/model/weights.epoch_99.hdf5
163/163 [==============================] - 96s 590ms/step - loss: 0.0983 -
acc: 0.9661 - val_loss: 3.8404 - val_acc: 0.5000
Epoch 100/100
162/163 [============================>.] - ETA: 0s - loss: 0.1069 - acc: 0
.9618Epoch 1/100
  1/163 [..............................] - ETA: 59s - loss: 4.4446 - acc:
0.5000
Epoch 00100: saving model to /content/data/model/weights.epoch_100.hdf5
163/163 [==============================] - 96s 586ms/step - loss: 0.1065 -
acc: 0.9620 - val_loss: 4.4446 - val_acc: 0.5000
Loading the best model
epoch: 56, val_loss: 0.8659762740135193, val_acc: 0.6875
20/20 [==============================] - 9s 443ms/step - loss: 0.9670 - ac
c: 0.7756
20/20 [==============================] - 12s 597ms/step
CONFUSION MATRIX ------------------
[[104 130]
 [ 10 380]]

TEST METRICS ----------------------
```
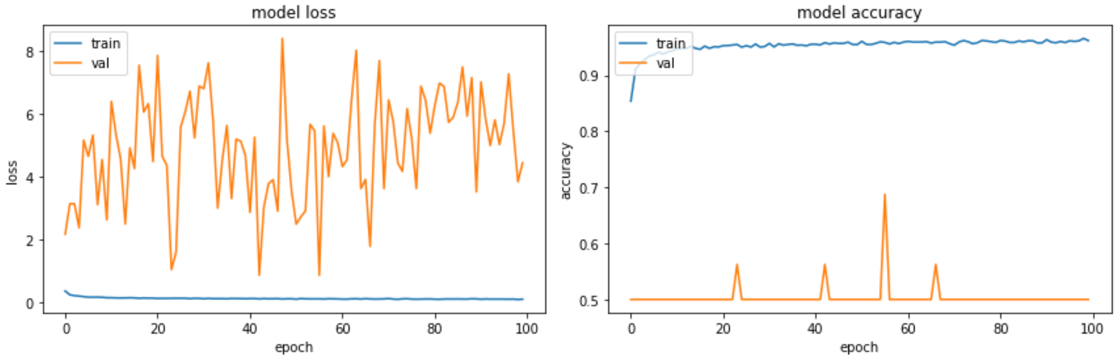

```
Accuracy: 77.56410256410257%
Precision: 74.50980392156863%
Recall: 97.43589743589743%
F1-score: 84.44444444444444

TRAIN METRIC ----------------------
Train acc: 96.20398879051208%
```



png