

# From Pixels to Predictions:

## Exploring CNN Models for Classifying X-ray Images in Respiratory Health

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# OUTLINE

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- Executive Summary
- Introduction
- Methodology
- Results Summary
  - Data Gathering and Description
  - Data Quality Assessment
  - Data Preprocessing
  - Data Exploration
  - Model Development, Validation, and Selection
- Detailed Findings
- Conclusion
- Appendix

# EXECUTIVE SUMMARY

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- **Study Objective**

- Conduct data analysis and modeling of x-ray images (categorized as Normal, Viral Pneumonia, and COVID-19) by developing multiple convolutional neural network classification models that could automatically learn hierarchical features directly from raw pixel data. Upon comparison and evaluation of candidate models, the final classification model will be selected based on robust performance estimates.

- **Methodology and Tools**

- Data Quality Assessment using Python OpenCV, Pandas, and NumPy APIs
- Data Preprocessing using OpenCV, Tensorflow, and Keras APIs
- Data Exploration using Python, Matplotlib, and Seaborn APIs
- Model Development and Validation using Python Scikit-Learn, Tensorflow, and Keras APIs

- **Overall Findings**

- Results were consolidated using the following GitHub URLs: [Python Notebook](#) | [Markdown Presentation](#)
- Differences in image pixel characteristics were observed between the x-ray image categories.
- X-ray image categories were modeled using different variations of the convolutional neural network model.
- Final prediction model was selected among candidates using robust classification performance.

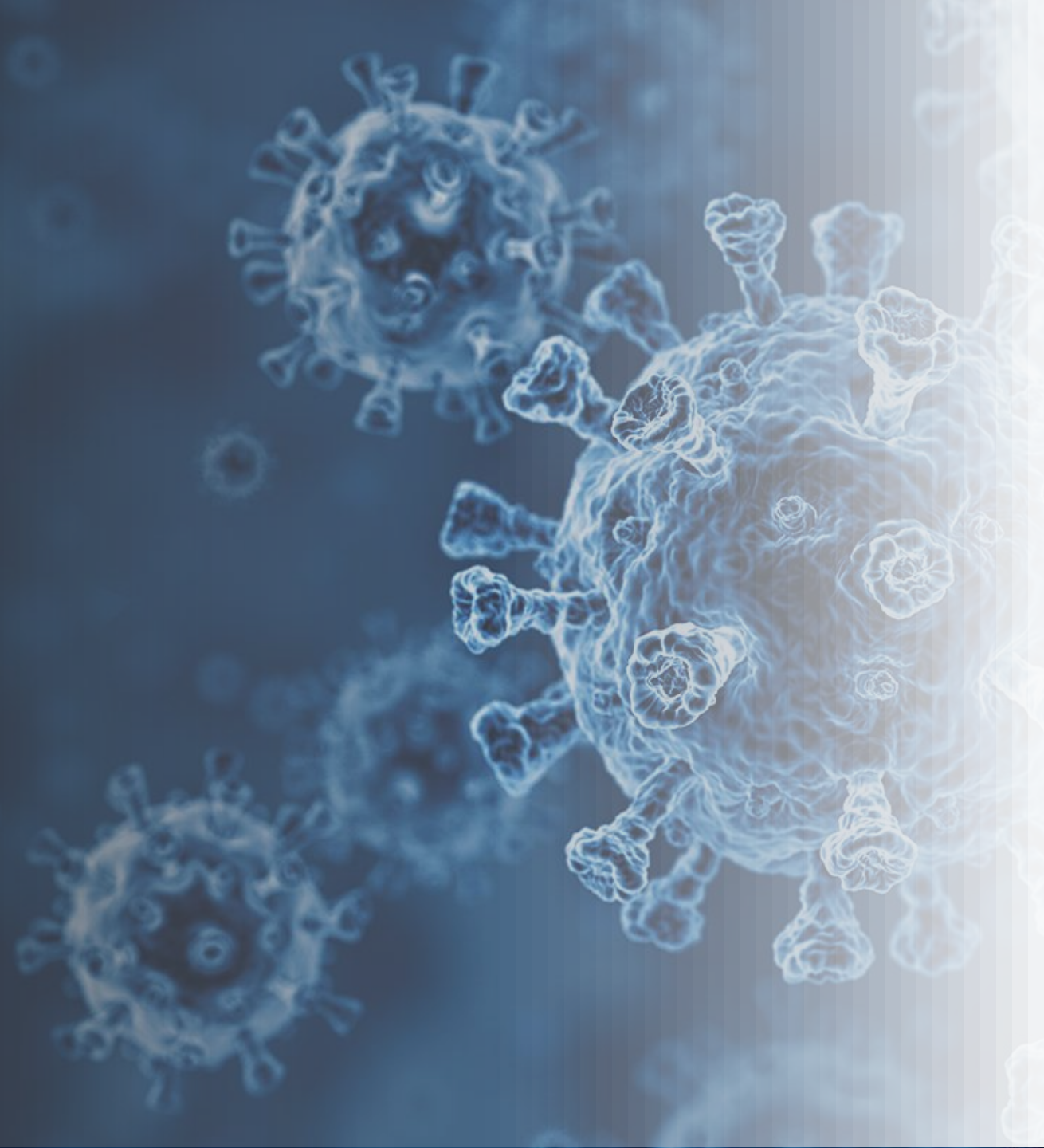
# INTRODUCTION

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- In recent years, the integration of artificial intelligence (AI) into healthcare has emerged as a transformative force, revolutionizing the way we approach diagnostics and treatment. The urgency of the COVID-19 pandemic has underscored the **critical need for rapid and accurate diagnostic tools**. One such innovation that holds immense promise is the development of AI prediction models for classifying X-ray images in respiratory health.
- **This capstone project generally aims to develop a prediction model that could provide robust and reliable predictions of x-ray images differentiating normal, viral pneumonia, and COVID-19 respiratory health conditions.**
  - In particular, multiple convolutional neural network classification models will be formulated to automatically learn hierarchical features directly from raw pixel data. The final classification model will be selected among candidates based on robust performance estimates. The final model performance and generalization ability will be evaluated through internal validation.

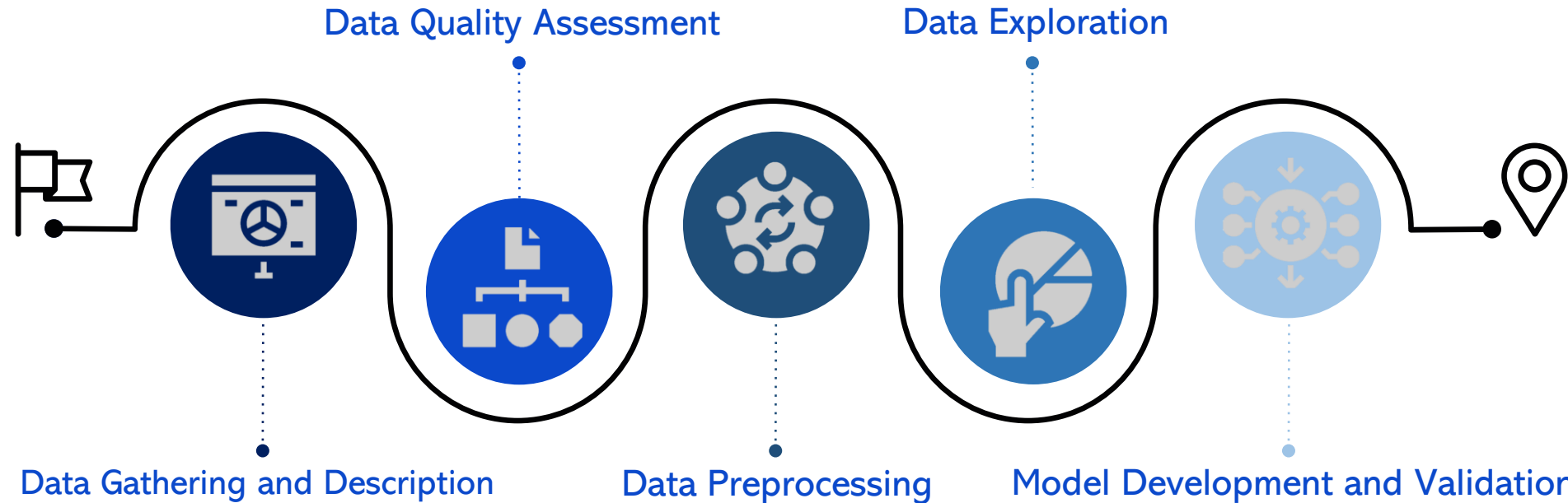
Section 1

# Methodology





# METHODOLOGY



- Data download
- Image characteristics
- Image dimensions

- Duplicate images
- Null images

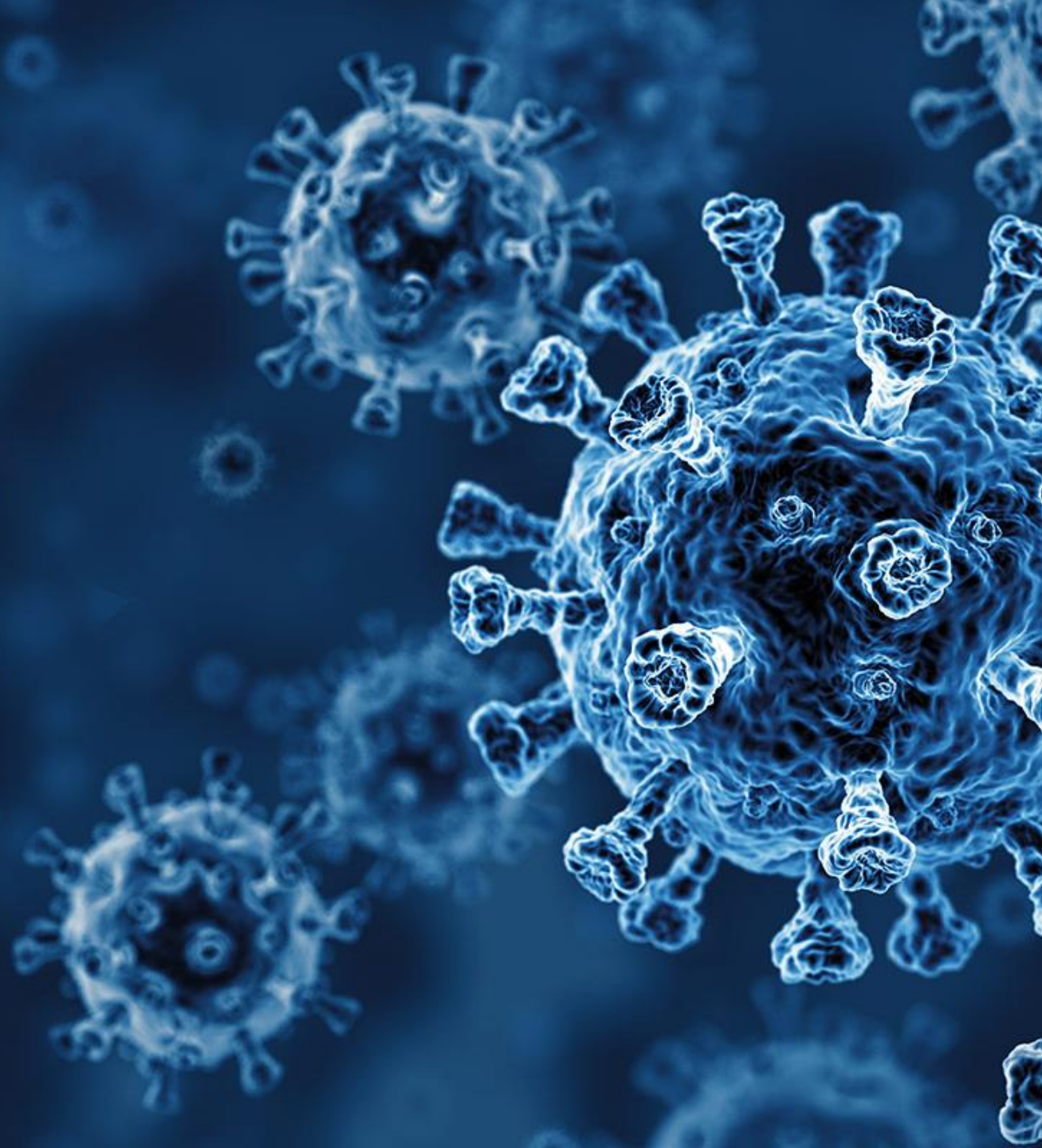
- Rescaling
- Rotation
- Height and width shift
- Horizontal flip
- Vertical flip
- Shear transformation
- Zooming

- Pixel statistics
- Pixel distribution

- Model development
- Model regularization
- Model validation
- Model selection

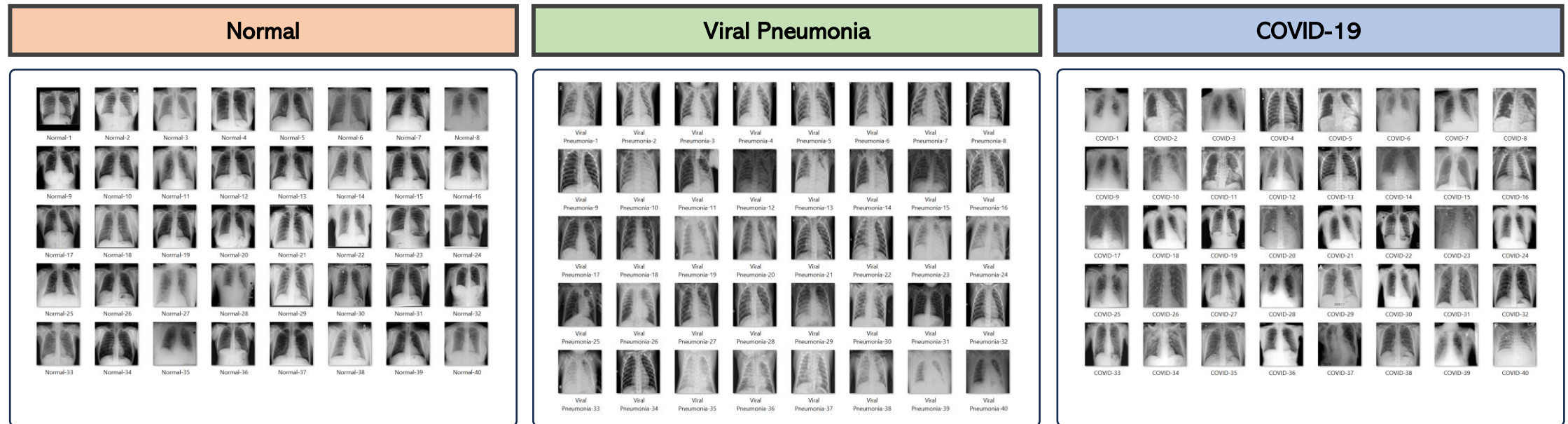
Section 2

# Results Summary



# RESULTS – DATA GATHERING

- A subset of an open [COVID-19 Radiography Dataset](#) from the [Kaggle](#) data repository (with all credits attributed to [Preet Viradiya](#), [Juliana Negrini De Araujo](#), [Tawsifur Rahman](#), [Muhammad Chowdhury](#), and [Amith Khandakar](#)) was used for the analysis as consolidated from different primary sources<sup>A</sup>.



## <sup>A</sup>Sources

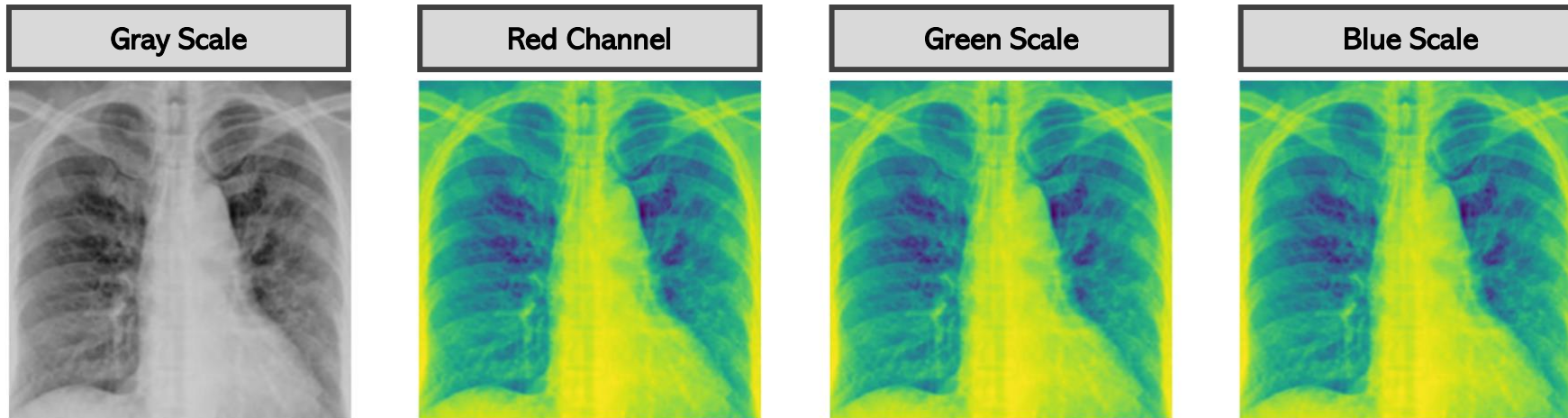
- Covid19 X-Ray Images from [BIMCV Medical Imaging Databank of the Valencia Region](#)
- Covid19 X-Ray Images from [GitHub: ML Group](#)
- Covid19 X-Ray Images from [Italian Society of Medical and Interventional Radiology](#)
- Covid19 X-Ray Images from [European Society of Radiology](#)
- Covid19 X-Ray Images from [GitHub: Joseph Paul Cohen](#)
- Covid19 X-Ray Images from [Publication: COVID-CXNet: Detecting COVID-19 in Frontal Chest X-ray Images using Deep Learning](#)
- Pneumonia and Normal X-Ray Images from [Kaggle: RSNA Pneumonia Detection Challenge](#)
- Pneumonia and Normal X-Ray Images from [Kaggle: Chest X-Ray Images \(Pneumonia\)](#)



# RESULTS – DATA DESCRIPTION

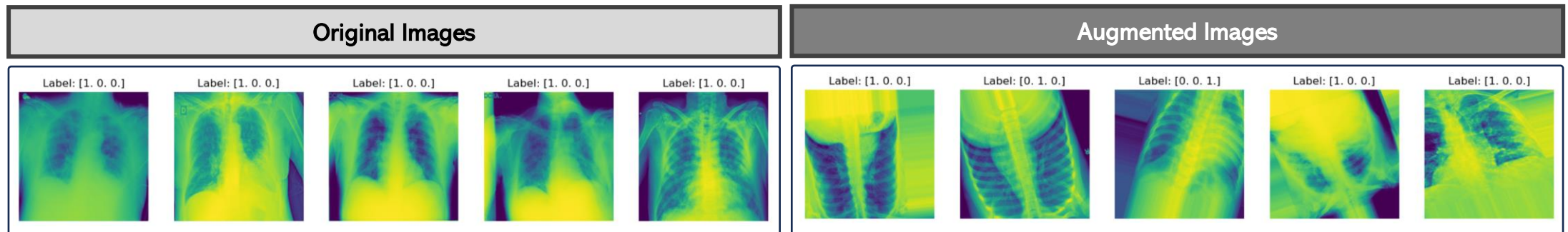
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- Overall dataset contains 3600 images broken down equally into 3 classes:
  - 1200 images labeled as **Normal**
  - 1200 images labeled as **Viral Pneumonia**
  - 1200 images labeled as **COVID-19**
- There were no duplicated or null images noted.
- Each image contains 3 channels – red, green, and blue with pixel values ranging from 0 to 255.
- Each image is in gray scale indicating that the pixel values for each channel are exactly the same.



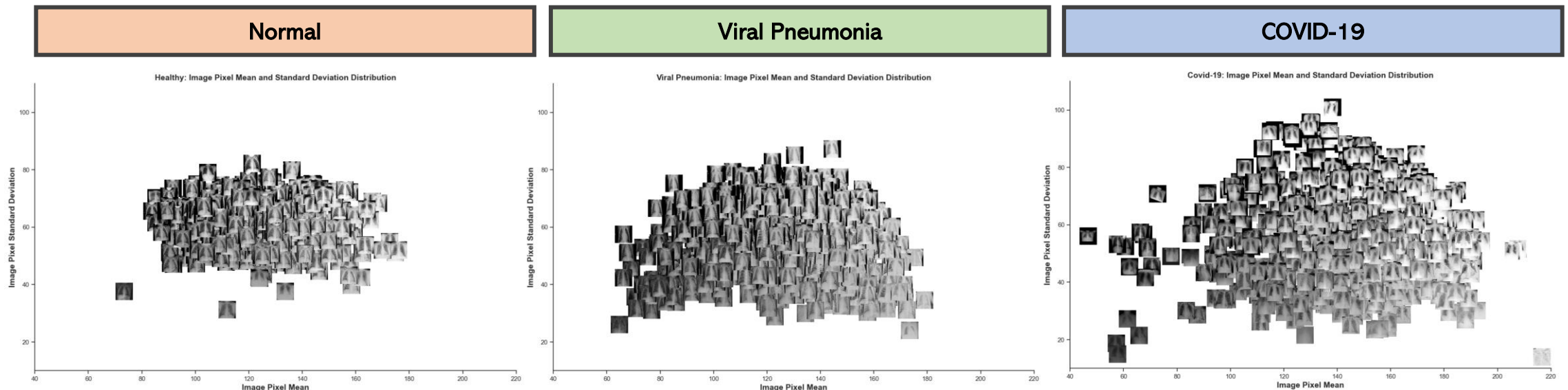
# RESULTS – DATA PREPROCESSING

- Different image augmentation techniques were applied using various transformations to the training images to artificially increase the diversity of the dataset and improve the generalization and robustness of the model:
  - **Rescaling** - normalization of the pixel values within the 0 to 1 range
  - **Rotation** - random image rotation by 20 degrees
  - **Width Shift** - random horizontal shifting of the image by 20%
  - **Height Shift** - random vertical shifting of the image by 20%
  - **Horizontal Flip** - random horizontal flipping of the image
  - **Vertical Flip** - random vertical flipping of the image
  - **Shear Transformation** - image slanting by 20 degrees along the horizontal axis
  - **Zooming** - random image zoom-in or zoom-out by a factor of 20%
- Training data included 2880 augmented images representing 80% of the dataset.
- Validation data included 720 original images representing 20% of the dataset.



# RESULTS – DATA EXPLORATION

- Distinct patterns were observed between the image categories.
- Images labeled as **Normal** were noted with lower mean pixel values (generally darker images) and a compact range of image pixel standard deviation values (stable and sufficient contrast).
- Images labeled as **Viral Pneumonia** were noted with higher mean pixel values (generally lighter images) and a wider range of image pixel standard deviation values (higher variation in contrast).
- Images labeled as **COVID-19** were noted with higher pixel values (collectively lighter images) and a wider range of image pixel standard deviation (extreme variation in contrast).



# RESULTS – MODEL DEVELOPMENT

- 4 convolutional neural network (CNN) models with varying levels of regularization were formulated.

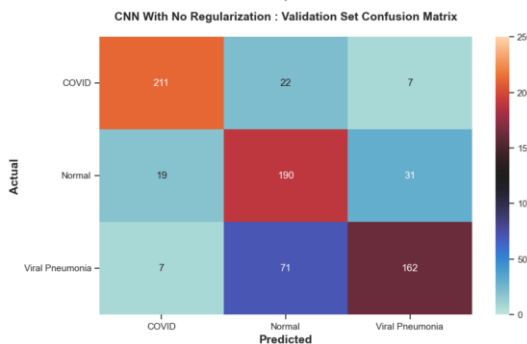
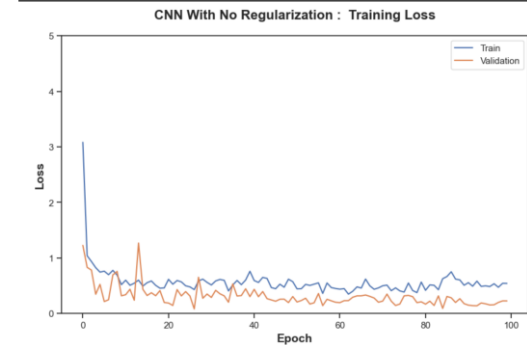
Model 1 CNN With No Regularization	Model 2 CNN With Dropout	Model 3 CNN With Batch Normalization	Model 4 CNN With Dropout + Batch Normalization
<b>Conv2D</b> Filters=32 Kernel Size=3x3 Activation=RELU Padding=Same	<b>Conv2D</b> Filters=32 Kernel Size=3x3 Activation=RELU Padding=Same	<b>Conv2D</b> Filters=32 Kernel Size=3x3 Activation=RELU Padding=Same	<b>Conv2D</b> Filters=32 Kernel Size=3x3 Activation=RELU Padding=Same
<b>Max_Pooling2D</b> Pool Size=2x2	<b>Max_Pooling2D</b> Pool Size=2x2	<b>Max_Pooling2D</b> Pool Size=2x2	<b>Max_Pooling2D</b> Pool Size=2x2
<b>Conv2D</b> Filters=64 Kernel Size=3x3 Activation=RELU Padding=Same	<b>Conv2D</b> Filters=64 Kernel Size=3x3 Activation=RELU Padding=Same	<b>Conv2D</b> Filters=64 Kernel Size=3x3 Activation=RELU Padding=Same	<b>Conv2D</b> Filters=64 Kernel Size=3x3 Activation=RELU Padding=Same
<b>Max_Pooling2D</b> Pool Size=2x2	<b>Dropout</b> Rate=0.25	<b>Batch Normalization</b>	<b>Batch Normalization</b>
<b>Flatten</b>	<b>Max_Pooling2D</b> Pool Size=2x2	<b>Activation</b> Activation=RELU	<b>Activation</b> Activation=RELU
<b>Dense</b> Units=128 Activation=RELU	<b>Flatten</b>	<b>Max_Pooling2D</b> Pool Size=2x2	<b>Dropout</b> Rate=0.25
<b>Dense</b> Units=3 Activation=SOFTMAX	<b>Dense</b> Units=128 Activation=RELU	<b>Flatten</b>	<b>Max_Pooling2D</b> Pool Size=2x2
	<b>Dense</b> Units=3 Activation=SOFTMAX	<b>Dense</b> Units=128 Activation=RELU	<b>Flatten</b>
		<b>Dense</b> Units=3 Activation=SOFTMAX	<b>Dense</b> Units=128 Activation=RELU
			<b>Dense</b> Units=3 Activation=SOFTMAX



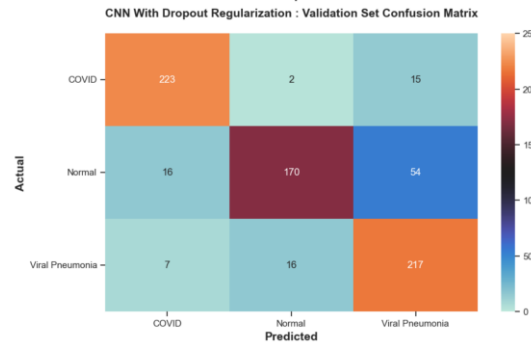
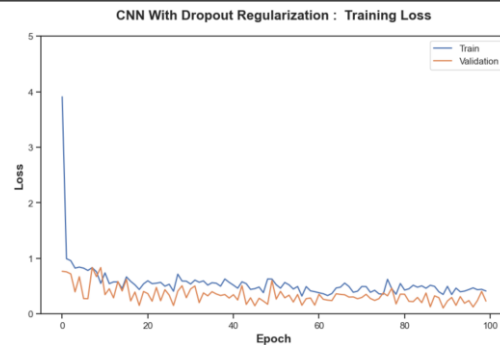
# RESULTS – MODEL VALIDATION

- Model 1 demonstrated 79.06% Precision, 78.19% Recall, and 78.25% F-Score on the validation set.
- Model 2 demonstrated 85.65% Precision, 84.72% Recall, and 84.57% F-Score on the validation set.
- Model 3 demonstrated 91.11% Precision, 90.97% Recall, and 90.97% F-Score on the validation set.
- Model 4 demonstrated 88.42% Precision, 87.36% Recall, and 87.44% F-Score on the validation set.

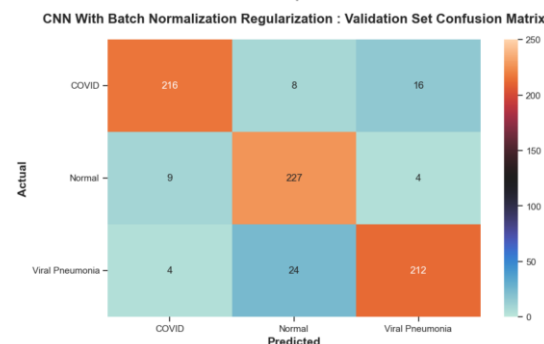
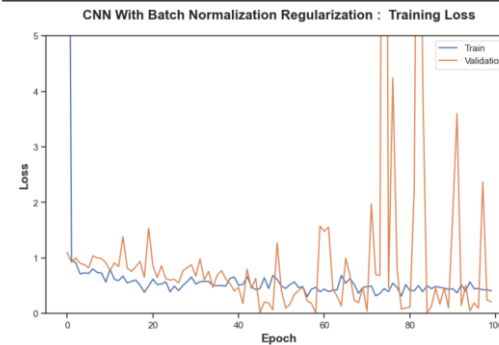
**Model 1: CNN\_NR**  
CNN With No Regularization



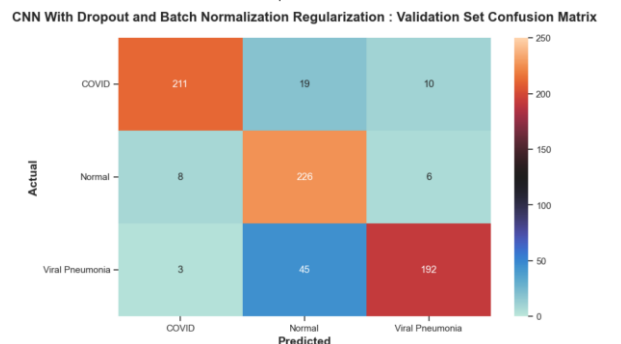
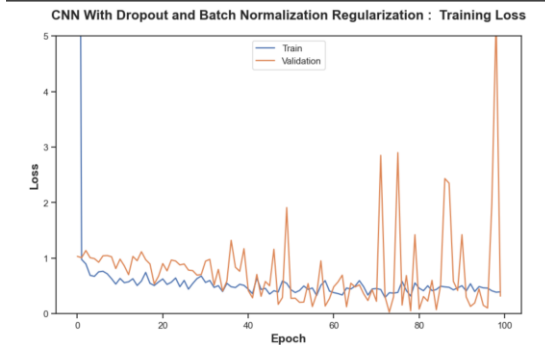
**Model 2: CNN\_DR**  
CNN With Dropout



**Model 3**  
CNN With Batch Normalization

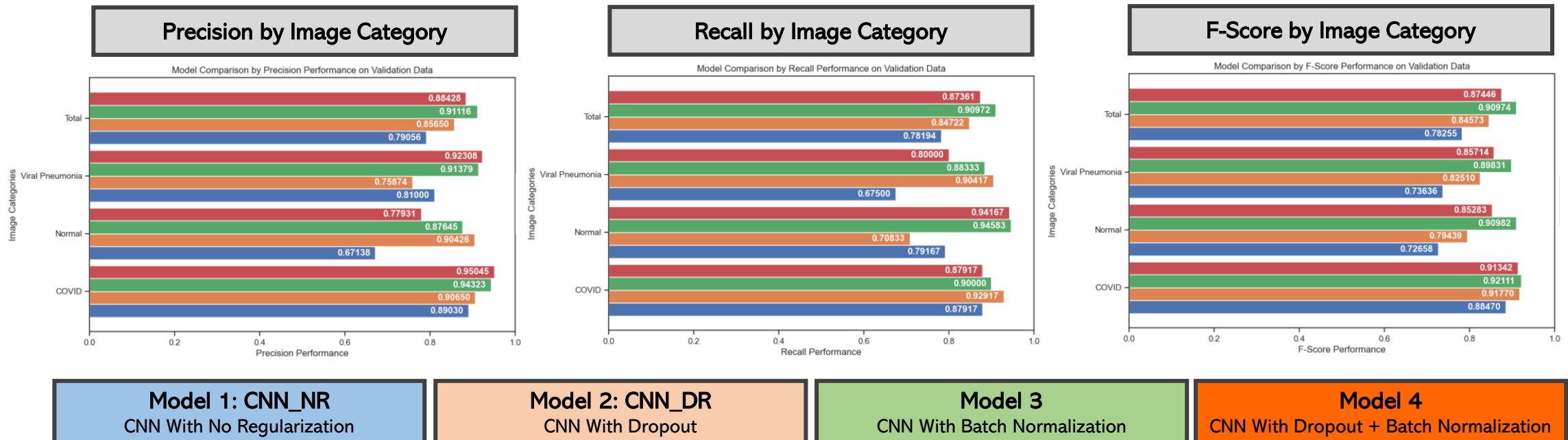


**Model 4**  
CNN With Dropout + Batch Normalization



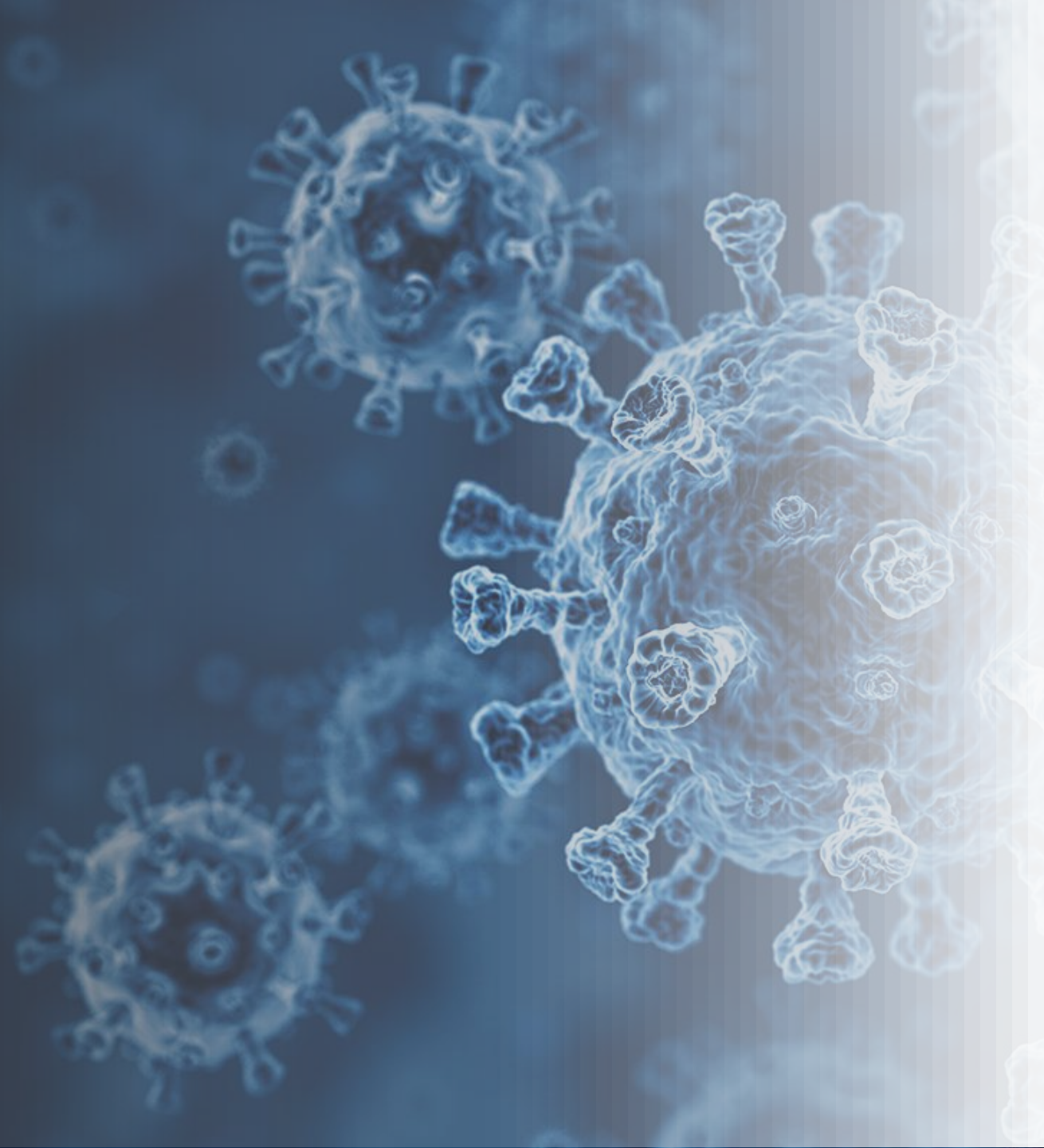
# RESULTS – MODEL SELECTION

- Model 3 – the CNN model with Batch Normalization had the best validation performance and was selected as the final model among all candidate models.
  - Overall - 91.11% Precision, 90.97% Recall, 90.97% F-Score
  - COVID-19 - 94.32% Precision, 90.00% Recall, 92.11% F-Score
  - Viral Pneumonia - 91.38% Precision, 86.33% Recall, 89.83% F-Score
  - Normal - 87.65% Precision, 94.58% Recall, 90.98% F-Score



## Section 4

# Summary



# CONCLUSION

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- **Key Findings**

- The final classification model using the **CNN model** which applied **batch normalization** as a regularization method provided robust and reliable image category predictions based on the estimated validation set metrics as follows.
  - Precision: 91.11%
  - Recall: 90.97%
  - F-Score: 90.97%

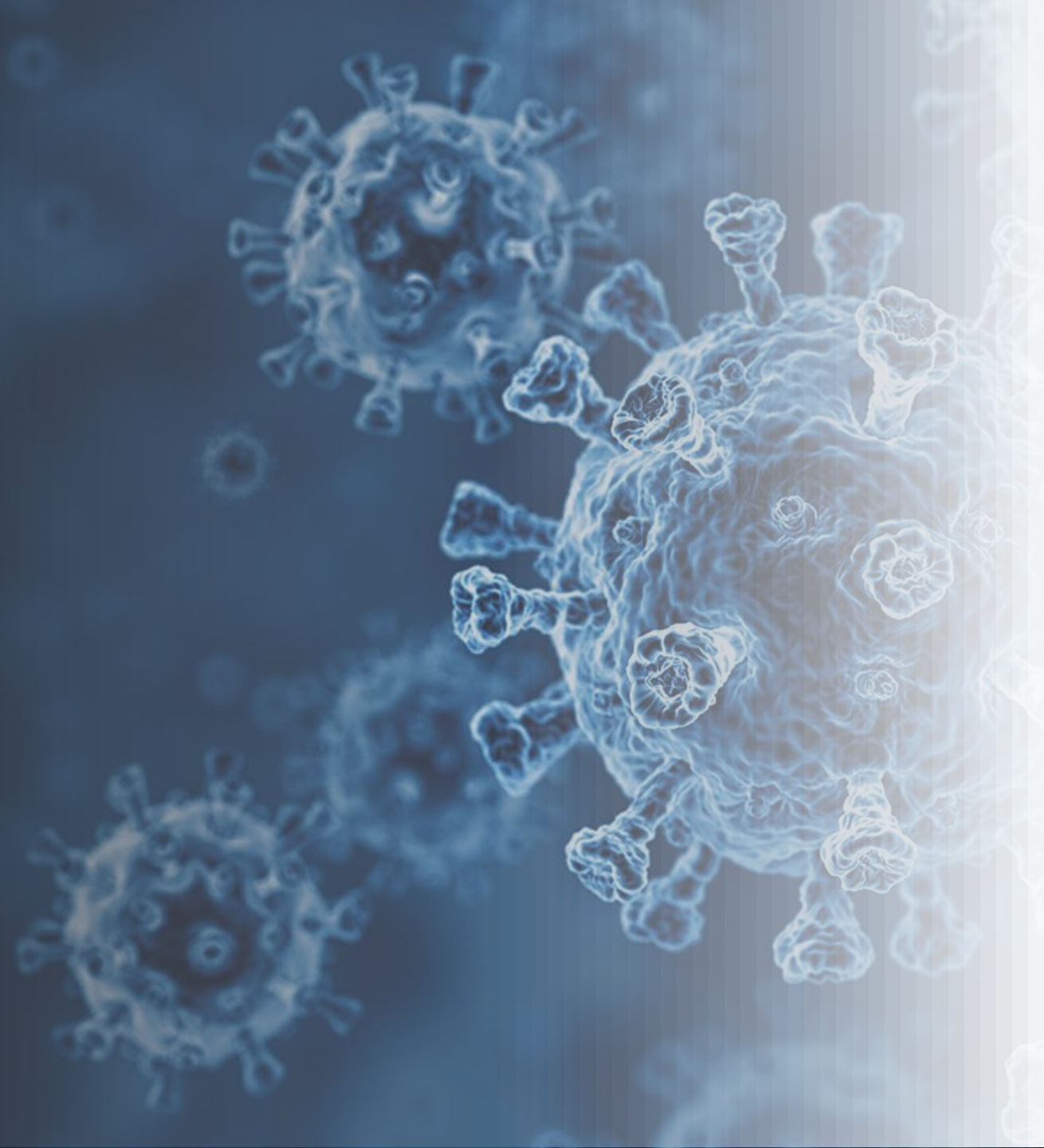
- **Next Steps**

- While the classification results have been sufficiently high, the current study can be further extended to achieve optimal model performance through the following:
  - Conduct model hyperparameter tuning given sufficient analysis time and higher computing power
  - Formulate deeper neural network architectures to better capture spatial hierarchies and features in the input images
  - Apply various techniques to interpret the CNN models by understanding and visualizing the features and decisions made at each layer
  - Consider an imbalanced dataset and apply remedial measures to address unbalanced classification to accurately reflect a real-world scenario



Section 5

# Appendix



# APPENDIX

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- Source Data

- Covid19 X-Ray Images: [BIMCV Medical Imaging Databank of the Valencia Region](#)
- Covid19 X-Ray Images: [GitHub: ML Group](#)
- Covid19 X-Ray Images: [Italian Society of Medical and Interventional Radiology](#)
- Covid19 X-Ray Images: [European Society of Radiology](#)
- Covid19 X-Ray Images: [GitHub: Joseph Paul Cohen](#)
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- Pneumonia and Normal X-Ray Images: [Kaggle: RSNA Pneumonia Detection Challenge](#)
- Pneumonia and Normal X-Ray Images: [Kaggle: Chest X-Ray Images \(Pneumonia\)](#)

# APPENDIX

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- Python Notebooks | Codes

- GitHub URL: [Data Background](#)
- GitHub URL: [Data Description](#)
- GitHub URL: [Data Quality Assessment](#)
- GitHub URL: [Data Preprocessing](#)
  - GitHub URL: [Image Description](#)
  - GitHub URL: [Image Augmentation](#)
- GitHub URL: [Data Exploration](#)
  - GitHub URL: [Exploratory Data Analysis](#)
- GitHub URL: [Model Development](#)
  - GitHub URL: [Premodelling Data Description](#)
  - GitHub URL: [CNN With No Regularization](#)
  - GitHub URL: [CNN With Dropout Regularization](#)
  - GitHub URL: [CNN With Batch Normalization Regularization](#)
  - GitHub URL: [CNN With Dropout and Batch Normalization](#)
- GitHub URL: [Consolidated Findings](#)

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**Thank You!**

