DAYANANDA SAGAR UNIVERSITY

KUDLU GATE, BANGALORE – 560068

Bachelor of Technology
in
COMPUTER SCIENCE AND ENGINEERING

Major Project Phase-II Report

IMPROVISING DEEP LEARNING TECHNIQUES FOR MEDICAL IMAGE ANALYSIS

By
Ananth Desai - ENG18CS0034
C D Karthik - ENG18CS0062
C Shrada - ENG18CS0072

Under the supervision of

Prof. Arjun Krishnamurthy
Assistant Professor

DEPARTMENT OF COMPUTER SCIENCE & ENGINEERING,
SCHOOL OF ENGINEERING
DAYANANDA SAGAR UNIVERSITY,
(2021 – 2022)

DAYANANDA SAGAR UNIVERSITY

School of Engineering
Department of Computer Science & Engineering
Kudlu Gate, Bangalore – 560068
Karnataka, India

CERTIFICATE

This is to certify that the Phase-II project work titled **"IMPROVISING DEEP LEARNING TECHNIQUES FOR MEDICAL IMAGE ANALYSIS"** is carried out by **Ananth Desai (ENG18CS0034), C D Karthik (ENG18CS0062), C Shrada (ENG18CS0072),** bonafide students of Bachelor of Technology in Computer Science and Engineering at the School of Engineering, Dayananda Sagar University, Bangalore in partial fulfillment for the award of degree in Bachelor of Technology in Computer Science and Engineering, during the year **2021-2022**.

Prof Arjun Krishnamurthy	**Dr Girisha G S**	**Dr. A Srinivas**
Assistant Professor Dept. of CS&E, School of Engineering Dayananda Sagar University	Chairman CSE School of Engineering Dayananda Sagar University	Dean School of Engineering Dayananda Sagar University
Date:	Date:	Date:

Name of the Examiner	**Signature of Examiner**
1.	
2.	

DECLARATION

We, **Ananth Desai (ENG18CS0034), C D Karthik (ENG18CS0062), C Shrada (ENG18CS0072)** are students of the seventh semester B.Tech in **Computer Science and Engineering**, at School of Engineering, **Dayananda Sagar University**, hereby declare that the phase-II project titled **"IMPROVISING DEEP LEARNING TECHNIQUES FOR MEDICAL IMAGE ANALYSIS"** has been carried out by us and submitted in partial fulfillment for the award of degree in **Bachelor of Technology in Computer Science and Engineering** during the academic year **2021-2022**.

Student **Signature**

Name1: Ananth Desai
USN: ENG18CS0034
Name2: C D Karthik
USN: ENG18CS0062
Name3: C Shrada
USN: ENG18CS0072

Place: Bangalore
Date:

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First, we take this opportunity to express our sincere gratitude to School of Engineering & Technology, Dayananda Sagar University for providing us with a great opportunity to pursue our bachelor's degree in this institution.

We would like to thank **Dr. A Srinivas. Dean, School of Engineering & Technology, Dayananda Sagar University** for his constant encouragement and expert advice. It is a matter of immense pleasure to express our sincere thanks to **Dr. Girisha G S, Department Chairman, Computer Science, and Engineering, Dayananda Sagar University**, for providing the right academic guidance that made our task possible.

We would like to thank our guide **Prof. Arjun Krishnamurthy, Assistant Professor, Dept. of Computer Science and Engineering, Dayananda Sagar University**, for sparing his valuable time to extend help in every step of our project work, which paved the way for smooth progress and the fruitful culmination of the project.

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LIST OF ABBREVIATIONS

CVS	Cervical Vertebrae Stages
CVM	Cervical Vertebral Maturation
AI	Artificial Intelligence
ML	Machine Learning
DL	Deep Learning

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ABSTRACT

Traditionally, lateral cephalograms have been employed in the diagnostic and treatment planning of orthodontic patients. The degree of ossification in bone is referred to as skeletal maturation. Since the wide spectrum in the timing and duration of the pubertal growth spurt and other developmental phases, chronological age is inaccurate for assessing developmental state. Doctors and clinicians must examine lateral cephalograms to determine the orthodontic procedure to be provided to the patient. Doctors manually classify the cephalograms into six stages based on the shape of the bones. Each of the classes has distinct diagnostic procedures. This procedure is time intensive and has the disadvantage of being subject to random and systematic error, most errors occur in landmark identification, which is based on observer experience, landmark definition, and image density and sharpness and hence requires expertise. Therefore, automating this process would provide a more reliable platform. We plan on training a deep learning model to successfully classify the lateral cephalograms into one of the six CVS stages: Initiation (CVS 1), Acceleration (CVS 2), Transition, (CVS 3), Deceleration (CVS 4), Maturation (CVS 5), Completion (CVS 6).

CHAPTER 1
INTRODUCTION

CHAPTER 1 INTRODUCTION

In the field of dental and maxillofacial radiology (DMFR), reports on AI and deep learning models used for diagnostic purposes and treatment planning cover a wide range of clinical applications, including automated localization of craniofacial anatomical structures/pathological changes, classification of maxillofacial cysts and/or tumours, and diagnosis of caries and periodontal lesions. Lateral cephalometry has been widely used for skeletal classification in orthodontic diagnosis and treatment planning. However, this conventional system, requiring manual tracing of individual landmarks, contains possible errors of inter and intra variability and is highly time-consuming.

Our project's goal is to create and evaluate an algorithm for determining cervical vertebral stages in lateral cephalograms, which will represent an individual's growth and development. Each cephalogram must be categorized into one of six phases. Each stage requires a unique set of diagnostic procedures to be performed on patients. We are currently acquiring lateral cephalograms collected by a Post Graduate student at the Dayananda Sagar Dental College. At present, the number of images received are ~670. Around 570 images have been undergone different pre-processing techniques.

1.1 PURPOSE

To develop and validate an artificial intelligence algorithm in the determination of cervical vertebral staging using lateral cephalograms. Given the data as the foundation for well-construction of models, with high quality and quantity of data, higher accuracy of predictive result and image interpretation can be achieved through the machine learning process. In the field of dentistry, a well-trained AI model can help not only in landmark identification but in all kinds of linear and angular measurements and volumetric measurements as well. It can save tremendous time by fully automated AI measurements so researchers will have more energy finding new insights within clinical examinations.

1.2 INTENDED AUDIENCE

Our research aims to assist doctors and clinical practitioners in accurately determining the CVS stage so that the patient can receive the appropriate orthodontic treatment. Since treatment varies for different CVS stages, a machine learning and deep learning approach will help validate the doctor's prediction. Patients, in the end, are the ones who gain from all of these procedures. Patients' health can improve when they receive an accurate diagnosis.

1.3 SCOPE OF THE PROJECT

Currently, many studies are utilizing artificial intelligence for the prediction, classification and clustering of real-life problems. Radiology is deemed to be the front door for Artificial intelligence (AI) into medicine as digitally coded diagnostic images are more easily translated into computer language. Machine learning is a key component of AI and is commonly applied to develop image-based AI systems.

CHAPTER 2
PROBLEM DEFINITION

CHAPTER 2 PROBLEM DEFINITION

Traditionally Cervical Vertebrae Stages have been analyzed by manually tracing lateral cephalograms, which is time-consuming and has the disadvantage of being subject to random and systematic error. Most errors occur in landmark identification, which is based on landmark definition, observer experience and image density and sharpness.

To overcome these problems machine learning and deep learning techniques have been increasingly applied. A well-trained AI model can help not only in landmark identification but in all kinds of linear and angular measurements and volumetric measurements as well. It can save tremendous time by fully automated AI measurements so researchers will have more energy finding new insights within clinical examinations.

CHAPTER 3
LITERATURE SURVEY

CHAPTER 3 LITERATURE REVIEW

Paper Title	**Source**	**Technology**	**Results**	**Inference**
Applications of Artificial Intelligence in Orthodontics	Taiwanese Journal of Orthodontics, 2020	Artificial intelligence (AI)	Applications	Finding insights in different kinds of information in the medical field.
Comparison of cephalometric measurements between conventional and automatic cephalometric analysis using convolutional neural network	Progress in Orthodontics, 2021	CNN	Comparative analysis	Adjustment needed for higher accuracy and better performance
Automated Skeletal Classification with Lateral Cephalometry Based on Artificial Intelligence	Journal of Dental Research, 2020	Multimodal CNN	Accuracy: 93.05%	The process and how they achieved the accuracy.
Automated Adenoid Hypertrophy Assessment with Lateral Cephalometry in Children Based on Artificial Intelligence	Diagnostics, 2021	CNN	Accuracy: 95%	Finding insights in different ways of working with lateral cephalograms.
Dental Characteristics of Different Types of Cleft and Non-cleft Individuals	Frontiers in Cell, Developmental Biology, 2021	AI		Adjustment needed for higher accuracy and better performance

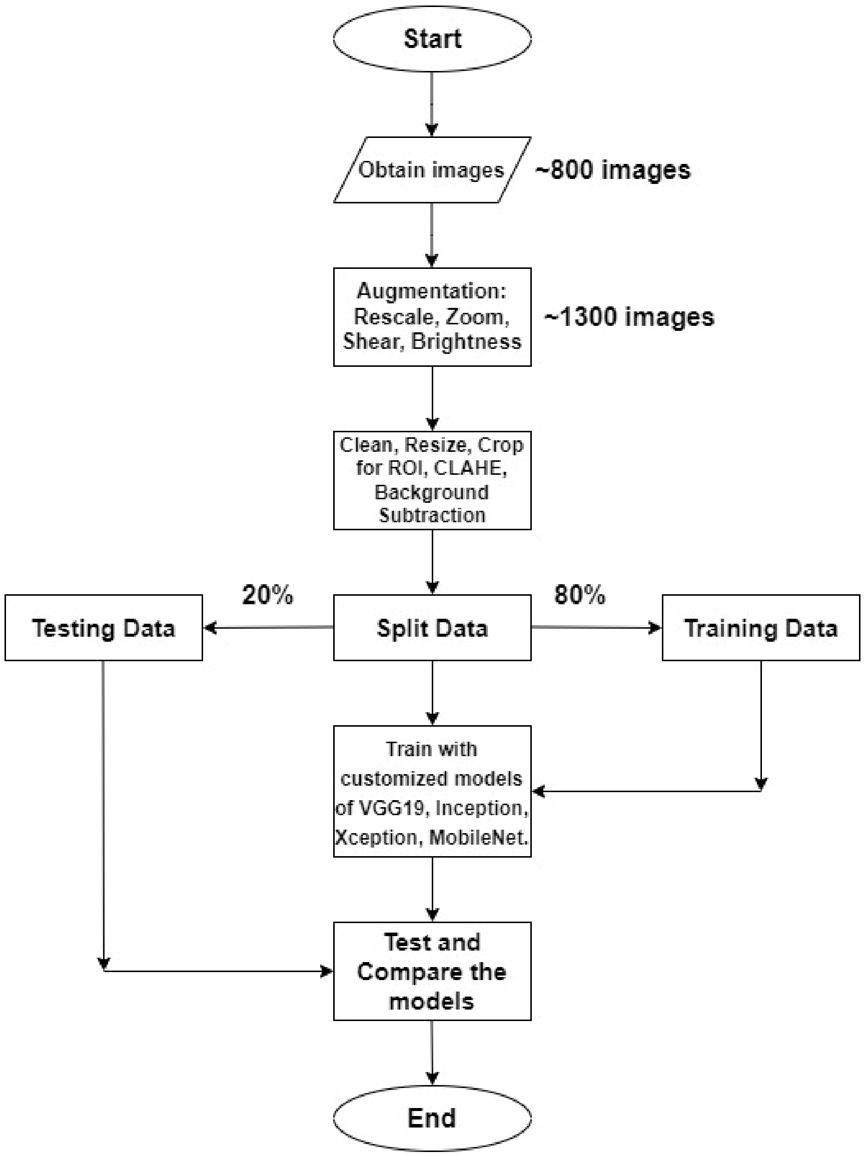
Realistic high-resolution lateral cephalometric radiography generated by progressive growing generative adversarial network and quality evaluations	PubMed Central, 2021	Progressive Growing GAN	Accuracy: 86%	Finding insights in different ways of working with lateral cephalograms.
Automatic 3D cephalometric annotation system using shadowed 2D image-based machine learning	2019, Physics in Medicine & Biology, Volume 64	DL	Point to point error is 1-1.5 mm	Experimenting with annotation systems before applying the algorithm.
Artificial Intelligent Model With Neural Network Machine Learning for the Diagnosis of Orthognathic Surgery	Journal of Craniofacial Surgery: October 2019	AI	Accuracy: 96% for Surgery/ non surgery decision. 91% for type of surgery	AI model using neural network machine learning could be applied for the diagnosis of orthognathic surgery cases.
Determination of the Cervical Vertebra Maturation Degree from Lateral Radiography	The 39th International Workshop on Bayesian Inference and Maximum Entropy Methods in Science and Engineering, 2019	DL	Accuracy: 90%	The process and how they achieved the accuracy

CHAPTER 4

PROJECT DESCRIPTION

CHAPTER 4 PROJECT DESCRIPTION

4.1. PROPOSED DESIGN



CHAPTER 5
REQUIREMENTS

CHAPTER 5 REQUIREMENTS

5.1 FUNCTIONAL REQUIREMENTS

- To determine cervical vertebrae stages in the selected lateral cephalograms obtained from a manual tracing of shape and size of the vertebrae.
- To derive an algorithm of artificial intelligence to determine cervical vertebral stages in the selected lateral cephalograms using the data obtained from manual tracing.
- To determine cervical vertebrae stages in the selected lateral cephalograms using artificial intelligence.
- To test and validate the developed algorithm in determining cervical vertebral stages in a different sample of cephalograms.

5.2 NON FUNCTIONAL REQUIREMENTS

- The accuracy of the algorithm must be maintained and the performance must not be compromised.
- The testability and the reliability of the software are some of the main requirements.
- The algorithm developed must be fair by all means, and must not cause any issues in trust or transparency.
- Efforts have to be put in to make the software secure and make the data private to the user.

CHAPTER 6
METHODOLOGY

CHAPTER 6 METHODOLOGY

6.1 DATASET ACQUISITION

The data is being collected by a Post Graduate Student in Dayananda Sagar Dental College. It consists of 800 images of Lateral Cephalograms.

- A considerable amount of time was dedicated to the collection of cephalograms.
- The raw data in SVG format was converted to JPEG format during the process of digitalization.
- The classification of the data was done manually, and the respective labels were entered into a CSV file.
- The lateral cephalograms are categorized according to their CVS stages. There are 6 CVS stages: Initiation (CVS 1), Acceleration (CVS 2), Transition, (CVS 3), Deceleration (CVS 4), Maturation (CVS 5), Completion (CVS 6).

6.2 DATA PRE-PROCESSING

The below steps were finalized after trying a series of various preprocessing techniques such as thresholding, contours, erosion, dilation, etc.

- **Resizing:** The images are resized according to the requirement. The original images were of 1804px width and variable height. The images were resized to 1800x2100 based on the mean height of all the images.
- **Cropping:** The images were cropped based on the region of interest (ROI) i.e., C2, C3, C4 cervical vertebrae. The resulting images were of size 500x500.
- **Frequency Check:** The frequency of each CVS stage must be the same to avoid overfitting. So, we cap the frequency of each stage to 100 images while training the model.
- **CLAHE:** It is an image enhancement technique that is used for contrast enhancement. It helps make the image clearer, which in turn increases the accuracy of the prediction. We have applied CLAHE with a clipLimit of 2 for all the images.

6.3 MODELS

- Currently testing with various pre-trained models such as VGG16, VGG19, Inception. **VGG16**: VGG16 is a convolutional neural net (CNN) architecture, which is considered to be one of the excellent vision model architectures to date. It is 16 layers that have some weights.
- **VGG19**: VGG19 is a convolutional neural net (CNN) architecture that is 19 layers deep.
- **Inception**: It is a convolutional neural network for assisting in image analysis and object detection.

6.4 TRAINING THE MODEL

The model shall be trained using 80% of images. The metrics used are Accuracy.

- **Accuracy:** It is one of the metrics used for evaluating the classification models. Accuracy is the ratio of predictions the model got right to the total number of predictions.

6.5 TESTING THE MODEL

- The model shall be tested by using the remaining 20% of images to validate the accuracy and ensure that the model correctly classifies with minimal error.

CHAPTER 7
EXPERIMENTATION

CHAPTER 7 EXPERIMENTATION

We have experimented with various kinds of image preprocessing techniques to improve the quality of the scans. Some of them are listed below:

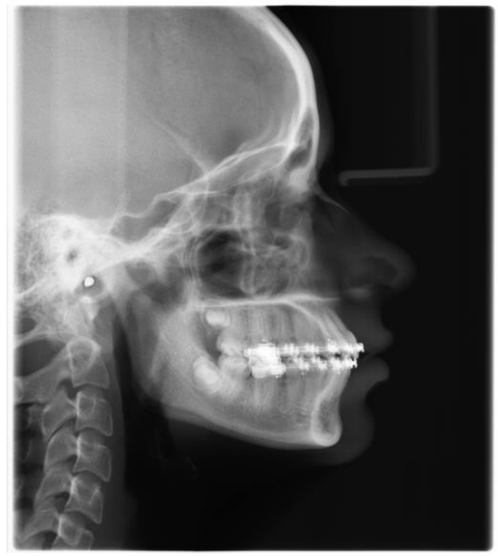


Figure 7.1: Original Scan

7.1 CROP AND RESIZE

- The region of interest is cropped from the original image and is then resized to 500x500 image.

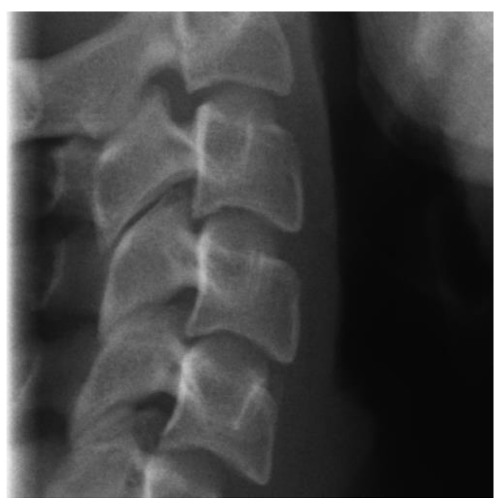


Figure 7.2: Cropped and Resized Scan

7.2 CLAHE (Contrast Limited Adaptive Histogram Equalization) AND BACKGROUND SUBTRACTION

- It is a variant **of Adaptive histogram equalization (AHE)** which takes care of over-amplification of the contrast. It is applied to improve the contrast of the images.
- Background subtraction is performed on the image after CLAHE is applied to get better insight on the shape of the bones.

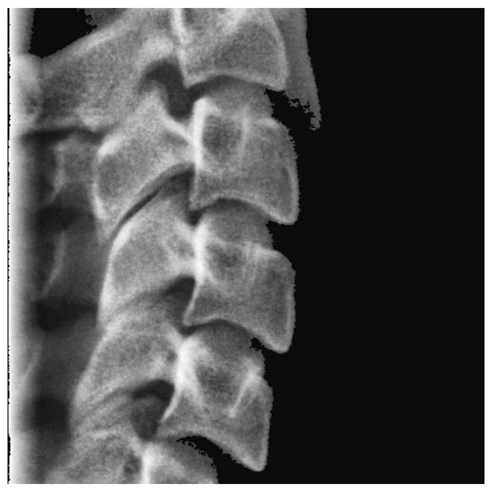


Figure 7.3: Image after CLAHE and Background Subtraction is applied

CHAPTER 8
TESTNG AND RESULTS

CHAPTER 8 TESTING AND RESULTS

8.1. TESTING

- The dataset obtained after application of the preprocessing methods mentioned in Chapter 7 was divided into two sections: Training and Testing set.
- We trained and tested the VGG19, Inception, Xception, MobileNet model using the training and testing dataset respectively.

8.2 RESULTS

8.1.1 VGG19

- we trained and tested the VGG19 model using the training and testing dataset respectively and obtained an accuracy of 88%.

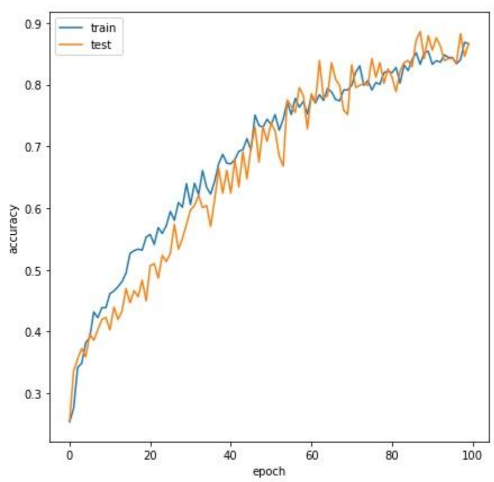


Figure 8.1: Accuracy obtained using VGG19

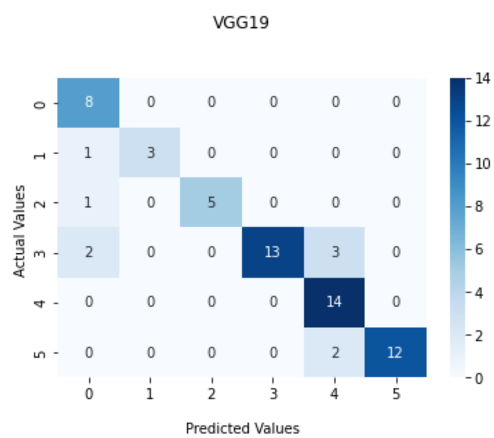


Figure 8.2: Confusion matrix using VGG19

8.2.2 INCEPTION

- we trained and tested the Inception model using the training and testing dataset respectively and obtained an accuracy of 87%.

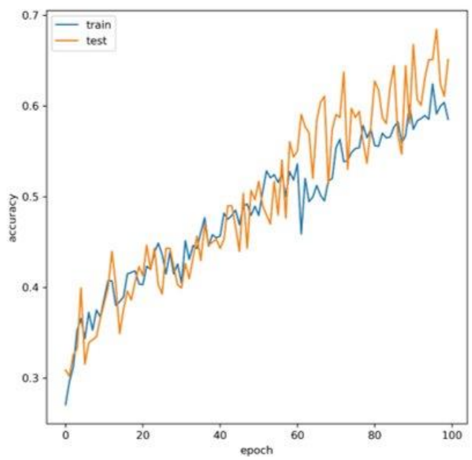


Figure 8.3: Accuracy obtained using Inception

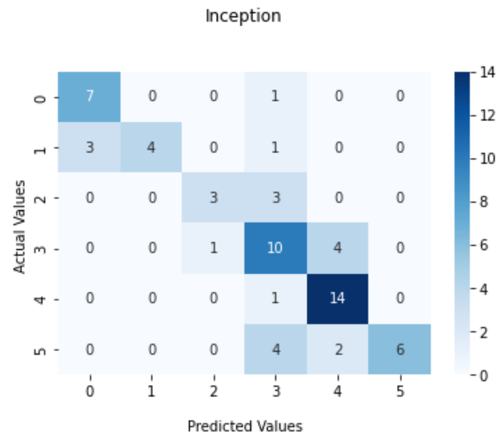


Figure 8.4: Confusion matrix obtained using Inception

8.3.3 XCEPTION

- we trained and tested the Xception model using the training and testing dataset respectively and obtained an accuracy of 90%.

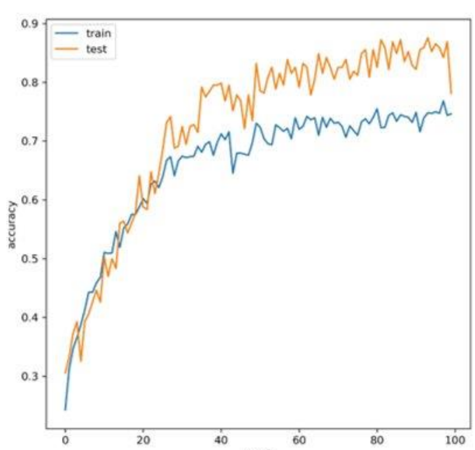


Figure 8.5: Accuracy obtained using Xception

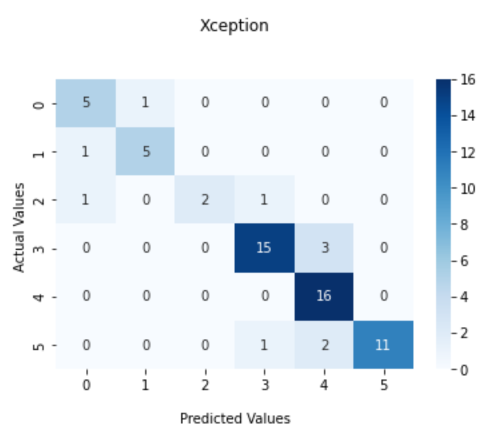


Figure 8.6: Confusion matrix obtained using Xception

8.3.4 MOBILENET

- we trained and tested the MobileNet model using the training and testing dataset respectively and obtained an accuracy of 96%.

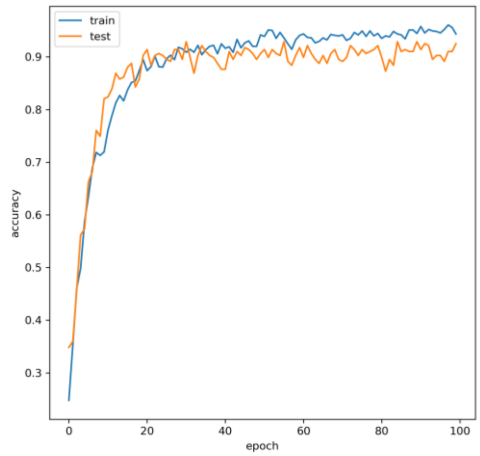


Figure 8.7: Accuracy obtained using MobileNet

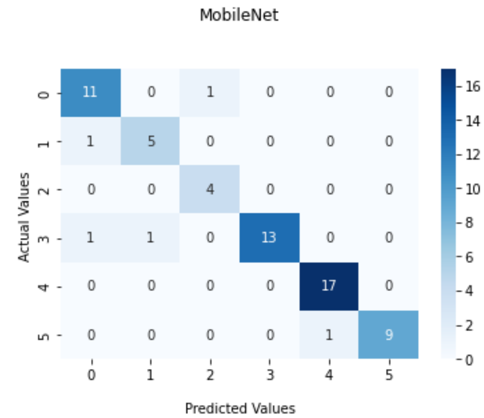


Figure 8.8: Confusion matrix obtained using MobileNet

8.5.5 COMPARISION

MODEL	ACCURACY
VGG19	88%
INCEPTION	87%
XCEPTION	90%
MOBILENET	96%

CHAPTER 9
CONCLUSION AND FUTURE WORK

CHAPTER 9 CONCLUSION AND FUTURE WORK

- VGG19 model has an accuracy of 88%. Inception model has an accuracy of 87%. Xception model has an accuracy of 90%. MobileNet model has an accuracy of 96%. In comparison, MobileNet model has the top accuracy and was able to achieve it within 20 epochs.
- Using the customized MobileNet model in real time would save a lot of time to the doctors in evaluating the stage of the lateral cephalogram and help them dedicate more time in patients.
- In the future, we can use CVS to determine the skeletal bone age of the lateral cephalogram. We can also automate this process using deep learning and transfer learning methods and save time of doctors.

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APPENDIX A
PUBLISHED PAPER DETAILS

ICAIHC 2022 ACCEPTANCE NOTIFICATION Inbox ×

ICAIHC-2022 <icaihc2022@gmail.com> Mon, 28 Feb, 15:58
to me, shradac, arjunkcontact

Dear Author(s),

It's our pleasure to inform you that your paper having paper id ICAIHC2022_paper_ 27 , with title " SKELETAL BONEAGE DETERMINATION USING DEEP LEARNING ", has been accepted for oral presentation and publication in the conference proceedings of ICAIHC2022.

However you are requested to update your paper as per the recommendations of the reviewers and prepare the camera ready paper accordingly.

You are required to register for the conference and upload the required documents **by 10th March 2022** in the given link https://forms.gle/J8AcGyAXhB2MTk1h8 .

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Please find here with the recommendations/comments of the reviewers for your ready reference.

Over all Evaluation: Accept with modification

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CERTIFICATE

This is to certify that C D Karthik has presented a paper entitled as "SKELETAL BONE AGE DETERMINATION USING DEEP LEARNING" in the **International Conference on Ambient Intelligence in Health Care (ICAIHC 2022)** held during 15th - 16th April 2022 organized by Department of Computer Application, Siksha 'O' Anusandhan Deemed to be University, Bhubaneswar, India.

Prof. (Dr.) Tripti Swarnkar
S'O'A Deemed to be University
(Program Chair, ICAIHC 2022)

Prof. (Dr.) Pabitra Mitra
IIT, Kharagpur
(General Chair, ICAIHC 2022)