الجمهورية الجزائرية الديمقراطية الشعبية
The People's Democratic Republic of Algeria
وزارة التعليم العالي والبحث العلمي
Ministry of Higher Education and Scientific Research
جامعة محمد بوضياف بالمسيلة
University Mohamed Boudiaf of M'sila

كلية الرياضيات والإعلام الآلي
Faculty of Mathematics and Informatics

قسم الإعلام الآلي
Department of Computer Science

Domain: Mathematics and Computer Science

Thesis Presented to Fulfill the Partial Requirement
for Master's Degree in Computer Science

Specialty: Information Systems and Software Engineering.

Prepared By: Rayane Aillane & Nada Chali

Supervised By:
Said Gadri

ENTITLED

Diagnosis of Dental State Using AI Techniques

Jury Members

Abdelbasset Barkat	President
Said Gadri	Supervisor
Noureddine Amraoui	Examiner

Academic year 2023/2024

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Dedications

I am deeply grateful to my parents, their love, their unconditional support and encouragement was essential throughout this route ,their constant belief in me, even during the most challenging times, has been a continuous source of inspiration and motivation.

To my brother, sisters, and friends, whose unwavering support, encouragement, and love have played an instrumental role in my journey of completing this thesis.

I owe them everything for their guidance, sacrifice, and faith in my abilities. This achievement would not have been possible without their love and unwavering support. With heartfelt appreciation and immense love, I dedicate this work to them, acknowledging their immeasurable impact on my life.

Rayane.

I dedicate this thesis to myself first because I did not give up despite all the difficulties I faced. I just want to say that you deserve this success. I'm very proud of you.

To the most compassionate person I have ever seen in this world, the one who supported me through thick and thin, who worked hard, took care of my upbringing, and showered me with her love and kindness. You have been my biggest supporter in my academic career. I cannot describe your kindness. To my beloved mother, may God protect her.

To the one who lit the lamp of my mind and extinguished my ignorance, to the one who sacrificed to illuminate my path, to my dear father, may God protect him.

Thank you for everything. All I hope is to always make you proud of me.

To those I lived with and grew up among, my brother and sisters.

To my friends who were always by my side during my difficult periods

To everyone who taught me a letter throughout my academic career.

Thank you all

Nada.

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List of Abbreviations

AI: Artificial Intelligence

WHO: World Health Organization

CT: Computed Tomography

MRI: Magnetic Resonance Imaging

CBCT: Cone Beam Computed Tomography

OPG: Orthopantomography

IOC: Intraoral Camera

X-ray: X-radiation

HIV: Human Immunodeficiency Virus

AIDS: Acquired Immunodeficiency Syndrome

HBV: Hepatitis B Virus

ML: Machine Learning

CNNs: Convolutional Neural Networks

DL: Deep Learning

LR: Logistic Regression

SVM: Support Vector Machines

RF: Random Forest

KNN: K-Nearest Neighbors

ANN: Artificial Neural Network

FNN: Deep Feed-Forward Neural Network

ReLU: Rectified Linear Unit Layer

RNNs: Deep Recurrent Neural Networks

NLP: Natural Language Processing

GPU: Graphics Processing Unit

CPU: Central Processing Unit

RAM: Random Access Memory

GUI: Graphical User Interface

PNG: Portable Network Graphics

GIF: Graphics Interchange Format

JPEG: Joint Photographic Experts Group

Glossary

Oral Cavity: Mouth.

Jaws: Either of two bones, the mandible or maxilla, forming the framework of the mouth.

Maxillofacial: Relating to the jaws and face.

Tissue: A group or layer of cells that work together to perform a specific function.

Soft Tissue: It is tissue that does not involve teeth or bone.

Bone: Refers to the hard, calcified structures within the body that provide support.

Mandible: The lower jawbone, which is the largest and strongest bone of the face.

Maxilla: The upper jawbone.

Anomalies: Condition in which one or more teeth deviate from the normal in form.

Restorations: Treatments used to restore the function of missing tooth structure.

Bridges: Type of dental restoration that replaces one or more missing teeth.

Extractions: Refer to the process of removing a tooth from its socket in the bone.

Abscesses: A localized collection of pus in the tissues of the body.

Fluoride: Chemical substance sometimes added to water or toothpaste to help keep teeth healthy.

Enamel: The hardest substance in the human body and serves as the wear-resistant outer layer of the dental crown.

Crown: Crown is a cap or covering for an existing tooth.

Metabolize: to change food into a form that can be used by your body.

Periodontal (gum) disease: Is an infection of the tissues that hold teeth in place.

Trauma: Trauma refers to any mouth injury.

Dental Caries: infectious condition that deteriorates the structure of teeth.

Pulpitis: Inflammation of the dental pulp.

Pulp: The soft tissue forming the inner structure of a tooth and containing nerves.

Tumors: An abnormal mass of tissue that forms when cells grow and divide more than they should.

GENERAL INTRODUCTION

1. Context of The Study

In recent years, technological advancements have significantly transformed various aspects of human life, and artificial intelligence (AI) stands out as a revolutionary force, AI has become an integral part of our society. AI involves the creation of computer systems capable of tasks that require human intelligence such as learning, reasoning, and decision-making, speech recognition. This is made possible by a subfield of AI known as machine learning. Machine learning is a subset of AI that focuses on the development of algorithms and statistical models that enable computers to learn from, and make predictions or decisions based on data. It has also become possible with what is known as deep learning. Deep learning which is a specialized subset of machine learning that involves the use of neural networks with many layers to model and understand complex patterns in data.

These modern technologies lead to significant improvements in various sectors such as manufacturing, logistics, healthcare, and finance. The integration of AI techniques in medicine represents a significant leap forward in medical technology and has opened new opportunities for advancements in healthcare. Dentistry, in particular, has embraced the potential of AI, which has a transformative potential in the field of dental diagnosis to enhance patient care, optimize clinical workflows, and offer promising alternatives by providing automatic, accurate, and quick diagnostic capabilities. AI assists in the early detection of dental issues, reducing human errors, subjectivity, and the time-consuming nature of traditional methods. Techniques such as machine learning and deep learning are being applied in diagnostic imaging, treatment planning, predictive analytics and robotic-assisted surgery by analyzing vast amounts of dental data. This approach provides new solutions to combat illnesses and improve public health.

2. Problem Statement

Despite the advancements in dental technology, accurate and timely diagnosis of dental state remains a challenge. Dental professionals are often required to interpret complex radiographic images and other diagnostic data, a process vulnerable to human error and subjectivity and time-consuming. This can lead to misdiagnosis, delayed treatment, and suboptimal patient care. There is a critical need for an efficient and quick system that can accurately classify teeth as damaged or normal, providing dentists with a reliable tool to assist in their diagnostic process. This thesis addresses this critical issue by exploring the use of AI techniques in dental diagnosis.

3. Objective

The main objective of this thesis is to develop an AI-based diagnostic system utilizing deep learning and machine learning techniques to aid in the diagnosis of dental conditions using panoramic radiographs, thereby enabling more accurate and faster diagnoses. This research aims to evaluate the accuracy and efficiency of the AI system in diagnosing dental conditions compared to traditional diagnostic methods, with the goal of supporting novice dentists and radiologists by providing a second opinion, ultimately leading to better patient outcomes.

4. Organization of The Manuscript

The present manuscript is divided into the following chapters:

General Introduction: This section provides an overview of the importance of AI in modern life, its relationship with dental diagnostics, the problem being addressed, the objectives of the thesis, and the structure of our thesis.

Chapter 1: Dental Diagnostic: This chapter start with overview of the field dentistry and their types, discuss common diseases, delves into the current state of dental diagnostics, the challenges faced by practitioners, and the emerging concept of smart dentistry. It discusses the potential benefits of integrating AI into dental practice.

Chapter 2: Deep Learning and Machine Learning: This chapter provides a detailed explanation of deep learning and machine learning techniques, their theoretical foundations, algorithms, and their applications.

Chapter 3: Implementation of the Proposed Solution: This chapter presents the practical implementation of the AI techniques discussed in the previous chapters. It includes the methodology, experimental part, data collection, and the analysis of results. Additionally, it evaluates the effectiveness of the AI-based diagnostic system and compares its performance with other methods and models that have been used.

Finally, we conclude our study with a conclusion, encompassing the key aspects of our project, including its advantages, limitations, and future possibilities.

CHAPTER 1

Dental Diagnostic

1.1. Introduction

Teeth are a unique and priceless treasure, and they have a functional purpose in eating, and in our aesthetic appearance. Therefore, it requires proper care. Accurate diagnosis leads to more successful treatment outcomes, which enhances oral health. Due to the great revolution brought about by the digital age and technology that has occurred in dentistry, it has become necessary to have effective mechanisms for accurate and useful medical tool in diagnosis.

In this chapter, we will start with an overview of the field of dentistry and its types. After that we will discuss common dental diseases, imaging diagnosis, its characteristics, disadvantages, various methods used for diagnosis especially Panoramic x-ray, along with the challenges encountered during diagnostics. Following that, we will explore the role of smart dentistry in enhancing the quality of dental care.

1.2. Presentation of The Field (Dentistry)

The term "dentistry" is derived from the Latin word "dens", which means teeth, and the suffix specific art or science. It is defined as the profession involved with the prevention and treatment of oral disease, which includes issues of the teeth, and diseases of the maxillofacial area. It also encompasses the correction of malformation of the jaws, misalignment of the teeth, and birth anomalies of the oral cavity [1].

As with medicine, the admission conditions, based on the average marks obtained in the baccalaureate, are set by a ministerial decree updated annually. We note that student who want to obtain the degree of Doctor in Dental field must pursue studies for six (06) years at the faculty of medicine. Teaching is provided in the form of lectures, tutorials, practical work and clinical internships as follows:

A preclinical cycle (1st, 2nd, and 3rd years): Internships are provided in laboratories.

A two-year clinical cycle (4th and 5th years): Courses and practical work are provided at the dental clinic.

Internship (6th year): A one-year internship, including the defense of an end-of-study thesis, and theoretical teaching in the form of conferences.

1.2.1. Types of Dentistry

- ***General Dentistry***

General dentistry focuses on the prevention, diagnosis, and treatment of a wide variety of dental conditions and diseases. General dentists provide basic dental care including routine exams such as cleanings, restorations, bridges, simple extractions.

- ***Dental Emergency***

A dental emergency requires any dental issue requiring immediate attention to eliminate powerful pain, stop continuation loss of the blood in the tissue, or save a tooth. This can include tooth pain, abscesses, broken teeth, and accidents to the mouth or gums.

- ***Aesthetic Dentistry***

Aesthetic dentistry, which is also referred to as cosmetic dentistry, is a field of dentistry that focuses on the enhancement of the appearance of the teeth, gums, and smile. This may encompass cosmetic enhancements and teeth whitening, all of which are designed to improve the overall appearance and aesthetics of the dental system.

- ***Implantology***

Implantology is a specialized field of dentistry that concentrates on the placement of artificial tooth roots into the lower jaw to support teeth. Implantology involves the surgical implantation of implants and the subsequent restoration of artificial teeth to reestablish function and aesthetics.

1.3. Common Dental Diseases and Their Causes

According to the World Health Organization (WHO), around 3.5 billion individuals worldwide, which is roughly 50% of the population, are affected by some sort of oral disease. Indeed, the worldwide prevalence of oral disorders surpasses the combined prevalence of the five most common non-communicable diseases by about one billion instances. India and China reported the highest number of cases, with India having 632 million cases and China having 599 million cases. On the other hand, Nauru and Tuvalu had the lowest number of cases, with Nauru having 5181 cases and Tuvalu having 4382 cases [2].

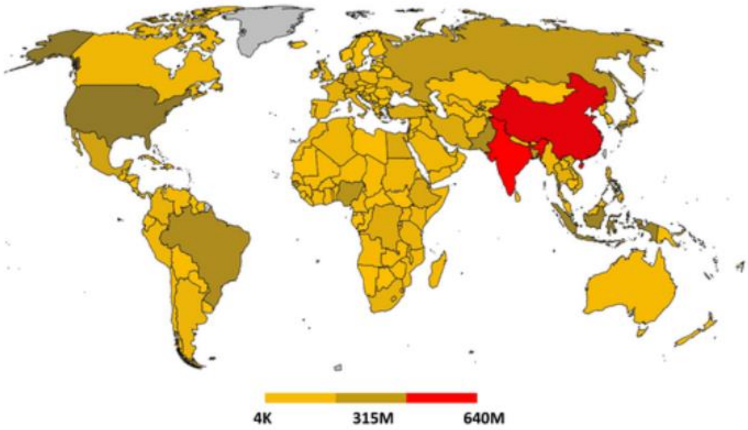


Figure 1.1: Spread of Dental Diseases in The World [2]

Dental diseases are widespread throughout the world for multiple and complex reasons. Firstly, these reasons include a lack of awareness of the importance of oral health, as poor dental care leads to an increased risk of cavities and gum disease. Secondly, an eating habits rich in sugars contributes greatly to the spread of tooth decay, in addition to a lack of exposure to fluoride, which strengthens tooth enamel. Also, smoking and alcohol consumption increase the risk of gum disease and oral cancer. Furthermore, poverty and lack of access to quality health care promote the spread of these diseases. Finally, bad habits such as not brushing teeth regularly and neglecting to visit the dentist also contribute to worsening the problem. Among the widespread and common diseases, we mention them below:

1.3.1. Dental Caries (Tooth Decay)

Dental caries is one of the most common chronic diseases worldwide, affecting individuals of all ages. It is a progressive destruction of the tooth structure. Dental caries is primarily caused by acid-producing bacteria, which metabolize sugars from food and produce acids as a result, that destroy the tooth over time. Dental caries is a common and preventable problem that necessitates a combination of excellent cleaning of the mouth, nutritional control, and routine professional treatment for maintaining ideal dental health [3].

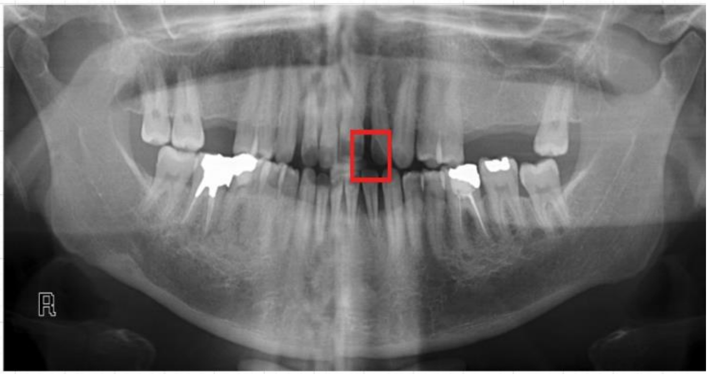


Figure 1.2: Example of Dental Caries From Our Dataset

1.3.2. Tooth Loss

The loss of teeth typically occurs as a result of long-term oral health issues, primarily extensive tooth decay and severe gum disease. However, it can also be caused by other factors, trauma, or other medical conditions such as diabetes or genetic factors. The estimated global average prevalence of complete tooth loss is almost 7% among people aged 20 years or older. For people aged 60 years or older, a much higher global prevalence of 23% has been estimated. Tooth loss can affect a person's ability to chew, speak, and maintain proper nutrition, bone loss, self-esteem issues. The best way to prevent tooth loss is to maintain good oral hygiene habits, such as brushing twice a day, flossing daily, and visiting the dentist regularly for cleanings and check-ups [4].

Figure 1.3: Example of Tooth Loss From Our Dataset

1.3.3. Oral Cancer

Oral cancer is one of the 10 most common cancers in the world. It is a cancerous growth that develops on the lip or inside the mouth. Tobacco smoking, alcohol consumption, and a weakened immune system are the main drivers of oral cancer in most countries. Oral cancer is more common in men and older people. As it progresses, it may cause symptoms such as mouth pain, difficulty swallowing, voice changes, speech impairment, ear pain, or lumps in the mouth or neck [5].

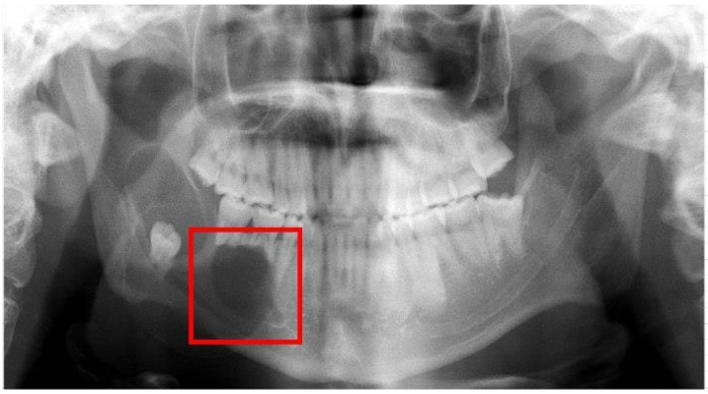


Figure 1.4: Example of Oral Cancer From Our Dataset

1.3.4. Pulpitis

Pulpitis is a dental condition characterized by inflammation of the dental pulp, which is the soft tissue inside the tooth containing nerves. It typically occurs as a result of bacterial infection, trauma, or other forms of damage to the tooth including fracture, decay, repeated dental procedures on the same tooth, or even aggressive tooth brushing. Pulpitis can cause severe tooth pain, sensitivity to sweet foods or drinks and trouble finding which tooth is causing the pain [6].

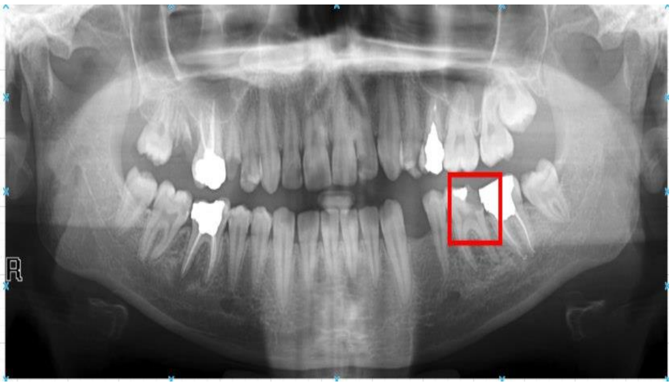


Figure 1.5: Example of Pulpitis From Our Dataset

1.4. Dental Diagnosis

Dental diagnosis is the process of identifying and understanding inside and outside the oral health issues through comprehensive examination and assessment, using scientific knowledge and also finding the relationship between them. It involves evaluating the patient's symptoms, medical history, clinical findings, and diagnostic tests to determine the underlying cause of dental problems. Several methods are used in dental diagnostic: clinical examination, patient history, radiographic imaging, laboratory tests, specialized examinations, diagnostic tests and digital tools. By combining these methods, dentists can accurately diagnose oral health problems and develop personalized treatment plans to address the patient's needs effectively. In this chapter, we will discuss and focus on radiographic imaging diagnostic. So, what is diagnostic imaging?

1.4.1. Diagnosis Imaging

Medical imaging is the method used for showing the structure and function of various tissues and organs in the human body. It is employed in clinical settings and medical research to examine the normal and abnormal anatomy and physiology of the body in great detail. Diagnostic imaging refers to the various techniques used to visualize the inside of the body for clinical analysis and medical intervention. These techniques include X-rays, computed tomography (CT), magnetic resonance imaging (MRI), ultrasound, and nuclear medicine [7]. Medical imaging is a key component in personalized medicine.

1.4.2. Diagnosis Imaging: Benefits

Over the past two decades a vast new tool of diagnostic techniques has revolutionized the practice of medicine and has completely transformed the field. It is now possible to capture highly detailed images of the whole human body, providing a comprehensive view of its anatomy. Because of its ability to offer quicker and more reliable information, diagnostic imaging has significantly improved patient outcomes and helped doctors achieve better results. The technology used in diagnostic imaging is not used for diagnosis purposes only. Diagnostic imaging benefits not just patients but also healthcare providers. and here are some benefits:

- ***Accurate Diagnosis***

Advanced imaging technologies provide detailed and precise images of the teeth, bones, and surrounding tissues to detect cavities, bone loss diagnosis, gum abscesses, gum cysts, aiding in accurate diagnosis and treatment planning [8].

- ***Early Detection***

Imaging techniques such as X-rays, CT scans, MRI, and ultrasound enable early detection and diagnosis of various medical conditions, including tumors, fractures, and internal injuries. Early detection allows for prompt intervention and treatment [7].

- ***Improved Patient Outcomes***

By enabling early detection and accurate treatment, imaging can significantly improve patient outcomes and survival rates [9].

- ***Monitoring Disease Progression***

Regular imaging can monitor the progression of diseases such as cancer, allowing for timely adjustments in treatment [9].

- ***Guidance for Treatment***

Imaging techniques helps guide treatment decisions by providing information on the size, location, and extent of abnormalities, assisting in planning surgeries or other interventions [7].

- ***Collaboration Between Fields***

Imaging results can be easily shared among healthcare providers, facilitating across disciplines collaboration and ensuring comprehensive patient care, especially in complex cases.

1.4.3. Diagnosis Imaging: Challenges and Difficulties

While imaging diagnostics offer numerous benefits and useful in modern medicine, they also have some disadvantages and limitations, below are its disadvantages:

- ***Radiation Exposure***

Although dental radiographs involve relatively low doses of radiation, repeated exposure can accumulate over time and pose health risks, particularly to sensitive populations such as children and pregnant women. Overuse of these techniques can increase the risk of radiation-related health issues, such as cancer, skin reddening and hair loss [10].

- ***Interpretation Variability***

The accuracy of diagnosis from dental images can be highly dependent on the skill and experience of the practitioner. There can be significant variability in interpretation, which may lead to misdiagnosis or over-diagnosis. On the other hand, less experienced radiologists may be more at risk to errors or misinterpretations [10].

- ***Cost***

High-quality imaging equipment and associated software can be expensive to purchase and maintain. This cost can be a limit for smaller practices and may increase the cost of dental care for patients.

- ***Technical Errors***

Imaging techniques can be susceptible to errors that may compromise the diagnostic quality. These can result from patient movement, incorrect positioning, or equipment malfunctions.

- ***Environmental Impact***

The production, use, and elimination of X-ray equipment and materials can negatively impact the environment. The manufacturing process of these systems, along with the chemicals used in radiography, can contribute to environmental pollution.

1.4.4. Tools Used for Dental Imaging Diagnostic

Dental diagnostic relies on a combination of tools, techniques and methods, to assess a patient's dental health. Digital X-rays tools have been and continue to be one of the most common forms of diagnostic imaging for healthcare providers, where digital sensors are used instead of traditional photographic film. Dental X-rays are diagnostic tools that help dentists visualize the teeth, bones, and surrounding soft tissues to identify issues not visible during a regular examination, provide critical insights for detecting decay, planning treatments, and diagnosing complex dental conditions. This technology allows for immediate image viewing and manipulation, significantly enhancing the efficiency and accuracy of diagnostic procedures. Let us discuss some of them:

- ***Cone Beam Computed Tomography (CBCT)***

CBCT is a diagnostic imaging modality that have ability to provide detailed three-dimensional images of dental and characteristics of the face structures and used when regular dental or facial x-rays are not sufficient. The name "Cone Beam Computed Tomography" reflects both the unique cone shaped X-ray beam used in the scanning process and the computed tomography technique employed to reconstruct detailed 3D images of the scanned area. Furthermore, for patients who chose to replace their missing teeth, the dentist can carefully examine, diagnose, and virtually position a dental implant in the patient's mouth using a computer in front of the patient before starting the processing [11].

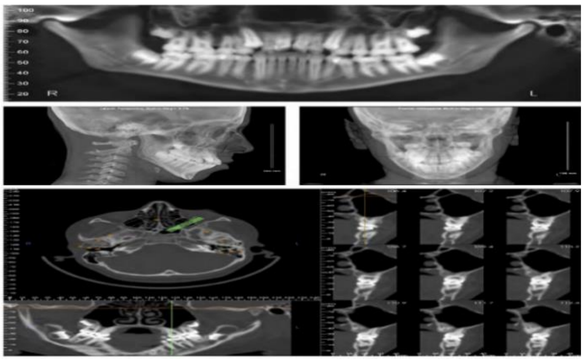


Figure 1.6: CBCT Radiography [12]

- ***Periapical Radiography***

Periapical radiographs ("peri" meaning "around" and apical meaning "apex" or end of tooth root). Type of dental radiograph commonly used if the dentist needs a good overview of the whole tooth or jaw, a periapical radiograph is the best choice. This type of dental radiograph captures an image of the entire tooth, including just beyond the root of the tooth. A periapical radiograph often catches the complete set of upper or lower teeth in a single image. This particular form of x-ray is employed when the dentist has suspicions regarding potential harm to the root tip of the tooth or an issue with the mandible [9].

Figure 1.7: Periapical Radiography [13]

➢ ***Panoramic Radiography***

Panoramic radiography or panoramic x-ray, also known as orthopantomography (OPG), is a diagnostic imaging method frequently used in dentistry that creates a detailed two-dimensional image of the entire mouth in a single exposure. This means that it is a panoramic scan for the upper and lower jaw. In order to analyze the general dental and bone structure, diagnose pathological diseases, plan treatments, a panoramic radiograph offers a comprehensive overview that is helpful. Panoramic dental x-ray uses a very small dose of ionizing radiation to capture the entire mouth in one image has a simplicity of application, less time requirement, and also great patient comfort. Thus, pediatric, handicapped, and senior patients would benefit greatly from a Panoramic imaging system compared to intraoral systems. On the other hand, the images resulting from the soft tissues will be poor and not clearly, the superimposition of different structures may hinder the correct interpretation of examinations and can sometimes be misleading [14].

Figure 1.8: Panoramic Radiography [14]

➢ ***VELscope***

The VELscope, or Visually Enhanced Lesion Scope, is a diagnostic device designed to enhance the visualization of abnormalities in the oral mucosa, such as potentially malignant and cancerous lesions. It operates by using tissue autofluorescence. This fluorescence allows healthy tissue to appear apple green, while abnormal tissue, which loses its fluorescence, shows up darker [15].

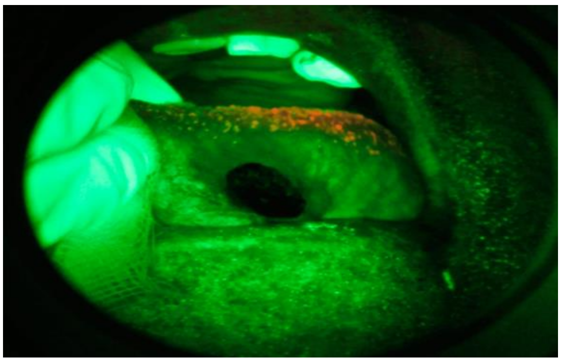


Figure 1.9: Velscope [15]

➢ ***Intraoral Camera***

An intraoral camera (IOC) is a diagnostic instrument primarily employed in dentistry clinics to capture accurate images of the interior of a patient's oral cavity. Dental cameras, typically designed in the form of wands, allow dentists to carefully examine teeth and other oral tissues, providing clear and detailed views that can be displayed on a monitor for both the dentist and the patient[16].

Figure 1.10: Digital Intraoral image [17]

1.5. Elements Covered by a Dental Diagnostic

A complete dental diagnostic usually encompasses multiple essential components that ensure an exact evaluation of a patient's oral well-being. The elements encompassed are:

➢ ***Visual and Tactile Examination***

The initial examination of the teeth and oral tissues is carried out using a flashlight, dental mirrors and specific instruments to detect visual abnormalities and textural changes.

➢ ***Patient Medical Records and History***

Information about the patient's general health, medical history, medications, and lifestyle habits can provide important clues for assessing the patient's specific dental risks and needs.

➢ ***Caries Screening***

Caries screening is the process of examining teeth to identify the prevalence of dental caries (cavities) at an early stage. This is typically obtained through visual inspection, tactile examination with dental tools, and rarely the use of radiographs (X-rays) [9].

➢ ***Evaluation of Gum and Periodontal Tissues***

This evaluation involves assessing the health of the gums and the structures that support the teeth, such as the periodontal ligaments and bone. This can include checking for signs of inflammation, pocket depth measurements, and radiographic evaluation to evaluate bone levels[14].

- ***Evaluation of Wisdom Teeth***

The evaluation of wisdom teeth involves assessing their position, development, and potential impact on surrounding teeth and tissues. This often includes a clinical examination and radiographic imaging (such as panoramic X-rays) [14].

- ***Oral Cancer Screening***

Oral cancer screening involves a thorough examination of the oral cavity to detect any signs of cancer or precancerous conditions. Special tools like VELscope might be used for enhanced detection [15].

1.6. Difficulties and Risk Factors During Diagnosis Process

A number of limitations to the clinical criteria for diagnosing dental disease are evident such as:

- ***Subjectivity and Variability***

Clinical decision-making in dentistry frequently depends on the dentist's subjective assessment, which can exhibit substantial variation among clinicians. The accuracy of clinical assessments can be influenced by factors such as the dentist's level of expertise, biases, and even fatigue [18].

- ***Time consumption***

Time consumption is a major challenge that arises during the process of dental diagnosis. Precise diagnosis frequently necessitates a comprehensive evaluation and detailed patient history, which can be a time-consuming process [19].

- ***Challenges with Visual and Tactile Examination***

Visual and tactile examinations, fundamental to clinical criteria, have limitations. For instance, visual inspection can be hindered by inadequate lighting, or patient factors such as limited mouth opening. So, focusing just on clinical factors may not always outcome sufficient accuracy for diagnosing dental diseases.

- ***Constraints in Early Disease Detection***

Clinical criteria frequently encounter difficulties in identifying the initial phases of conditions such as dental caries or periodontal disease. These disorders may not be visibly or clinically evident until they have advanced considerably, hence limiting the chance for early intervention and less invasive treatment methods.

- ***Education and Training***

The diagnostic accuracy of dental practitioners can be considerably influenced by their level of education and training. Diversity in training programmed across different locations and institutions result in inequalities in the competence of dentists in using clinical criteria [18].

- ***Health Conditions***

Health illnesses such as diabetes, autoimmune disorders, and HIV/AIDS could increase the risk of dental diagnostic issues especially the risk of infection after surgery.

- ***Transmission Risk***

Hepatitis B Virus HBV is a significant risk factor in dental diagnoses and treatment due to its implications for transmission due to its effects on blood-borne transmission.

To avoid these difficulties, we propose to use artificial intelligence in this field, by applying machine learning ML and DL techniques and applications which is called smart dentistry.

1.7. Smart Dentistry

Smart dentistry, or as known as ‘digital dentistry ' or ' tele dentistry ‘, this term refers to the integration of technology and advanced methodologies such as artificial intelligence (AI), machine learning, deep learning into the field of dentistry to enhance patient care, improve diagnostics, streamline treatment processes, to make automatic disease diagnosis and solving multiple clinical problems and making the work of clinicians easier.

Smart dentistry helps dentists develop customized treatment plans for patients by analyzing their dental records, medical history, and other relevant data. This ensures reducing human errors and achieving consensus in diagnosis among dentists, which accelerates the diagnostic process, and cost-effectiveness, reducing healthcare costs by improving efficiency and accuracy, maintaining accuracy and mitigating the impact of fatigue or oversight [20]

Deep learning, a type of artificial intelligence (AI), is utilized in diverse sectors of society, such as medicine and dentistry, to address practical challenges. Several recent studies indicate the high effectiveness of pathologic image analysis algorithms based on artificial intelligence (AI). Convolutional neural networks (CNNs), which are deep learning structures that can extract numerous features from abstracted layers of filters, are mostly utilized for analyzing vast and complicated images [21].

Machine learning algorithms include a diverse range of techniques and technologies that can be used for solving numerous tasks, such as classification, detection, segmentation, and prediction. ML is significantly improving the accuracy and efficiency of disease classification in dental diagnosis. These technologies leverage advanced algorithms to analyze complex datasets, such as digital images, also to identify and classify dental diseases [20].

1.7.1. Examples of Smart Dentistry Practices

➢ ***Smart Toothbrushes***

Smart toothbrushes are equipped with several advanced technology, including cameras and pressure sensors, to monitor brushing action and simulate an oral inspection during regular brushing. Using the camera's data, the dentist may check the person's teeth as they are brushing. Furthermore, pressure sensors might be employed to ascertain the accuracy of the brushing procedure.

The data can be shared with the dentist in real time, enhancing the process of preventive care. The intelligent toothbrush is capable of capturing intraoral images, which are subsequently transmitted to the server. Artificial intelligence algorithms would analyses these images and scan them for indications of cracks, cavities, or any other irregularities that necessitate the expertise of a specialist. If the initial scans reveal any worrisome findings, both the patient and the practitioner will receive notifications through mobile applications, prompting the patient to schedule an appointment at the dental clinic [22].

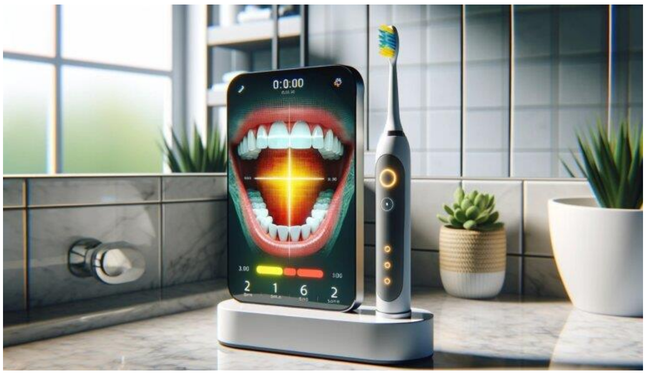


Figure 1.11: Smart Ttoothbrushes [22]

➢ ***Robotics in Navigational Surgery***

Advancements in technology and computer science has resulted in an increase in the use of robotics in navigational surgery across several medical fields. The field of dental surgery is seeing ongoing successes in robotics, leading to a continuous expansion of their applications. The integration of robotics into dental implantology aims to enhance the accuracy, excellence, and security of surgical treatments. The robotic system is capable of both pre-prosthetic planning and exact placement of dental implants in the exact the location. In recent times, the utilisation of robot-assisted surgery has been employed in the placing of dental implants. In 2017, the Food and Drug Administration approved the first robotic dental surgery system for implant treatments in United States [23].

Figure 1.12: Yomi Robotics [23]

- ***Smart Teeth***

The implantation of smart chips in the prosthesis or the removal of a portion of the old tooth to insert the chip could enable the monitoring of multiple variables. These implants would enable the development of "smart teeth" capable of detecting the pH of saliva, monitoring food intake, measuring the amount of acidic beverages and food taken, and determining blood alcohol levels. The collected data would be analyzed using artificial intelligence and big data analytics to identify patterns and correlations. This may lead to an increase in the practice of preventive dentistry, which is tailored to the specific recommendations for each patient [24].

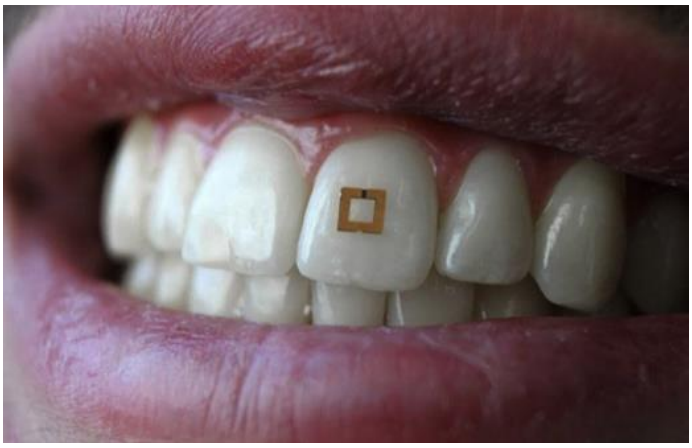


Figure 1.13: Smart Teeth [24]

1.8. Conclusion

In conclusion, the chapter introduces the field of dentistry, including diseases, types, and various diagnostic methods and its disadvantages. It also emphasizes the importance of artificial intelligence in the field of dentistry by presenting a set of classification approaches. The chapter paves the way for further exploration and development of effective mechanisms for dental diagnosis.

CHAPTER 2

Machine Learning and Deep Learning

2.1. Introduction

Artificial intelligence (AI) is a branch of computer science that focuses on creating machines capable of performing activities that would normally need human intelligence. These machines are designed to simulate human cognition and decision-making processes, allowing them to learn from experience and improve performance over time. Machine learning (ML) and deep learning (DL) are two branches of artificial intelligence (AI) that focus on creating algorithms and models capable of learning knowledge from data. This chapter aims to give a quick overview of artificial intelligence, machine learning, and deep learning, introduce the basic concepts of ML and DL, the difference between them, and provide an overview of applications and algorithms in this field.

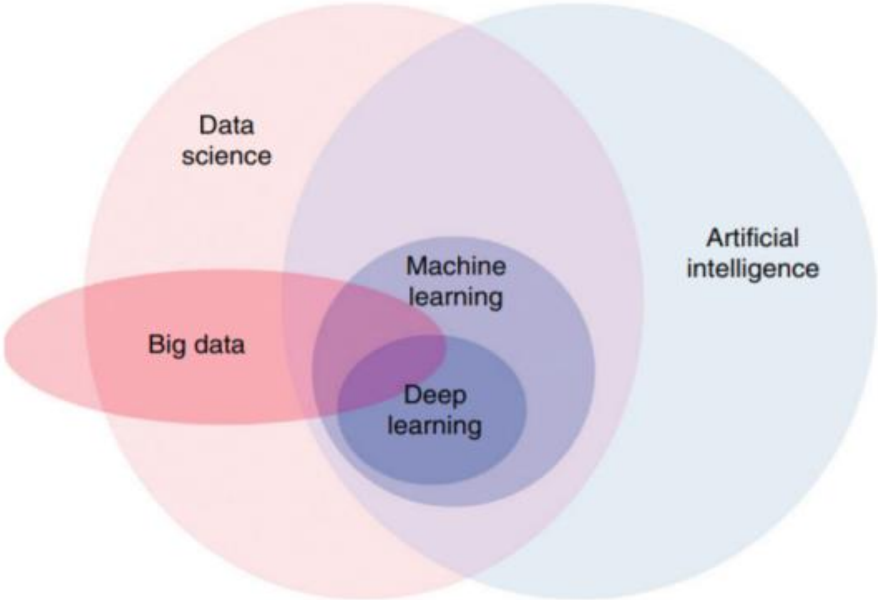


Figure 2.1: Key Elements of Artificial Intelligent Systems [25]

2.2. A Quick History of AI, ML and DL

Artificial intelligence (AI) began in the 1950s, marking the beginning of efforts to create machines capable of intelligent behavior. Early AI centered on symbolic reasoning and expert systems. Machine Learning (ML) began as a subset of AI in the 1950s and 1960s, with pioneers such as Arthur Samuel working to create algorithms that allow computers to learn from data and improve performance over time. Deep Learning (DL), a specialized kind of machine learning inspired by the structure of the human brain, gained popularity in the 2010s, aided by advances in processing power and the availability of massive datasets. Breakthroughs in deep learning, notably with neural networks, transformed domains such as computer vision, natural language processing, and robotics, catapulting AI into practical applications across sectors.

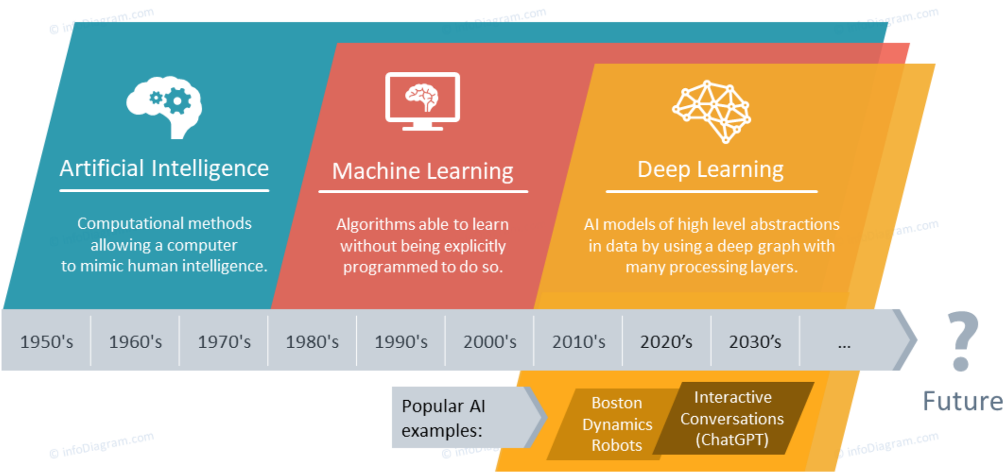


Figure 2.2: History of AI, ML and DL [26]

2.3. Machine Learning

Machine learning is a branch of artificial intelligence that uses statistical and mathematical approaches to allow computers to learn from data and make predictions or choices without being explicitly programmed to do so [27].

It entails training algorithms on large amounts of labeled or unlabeled data and utilizing that data to uncover patterns and relationships that can be utilized to make predictions or choices about new data [28].

2.4. Learning Types

Some of the main types of learning are as follows and shown in below figure:

- Supervised Learning
- Unsupervised Learning
- Semi-Supervised Learning
- Reinforcement Learning

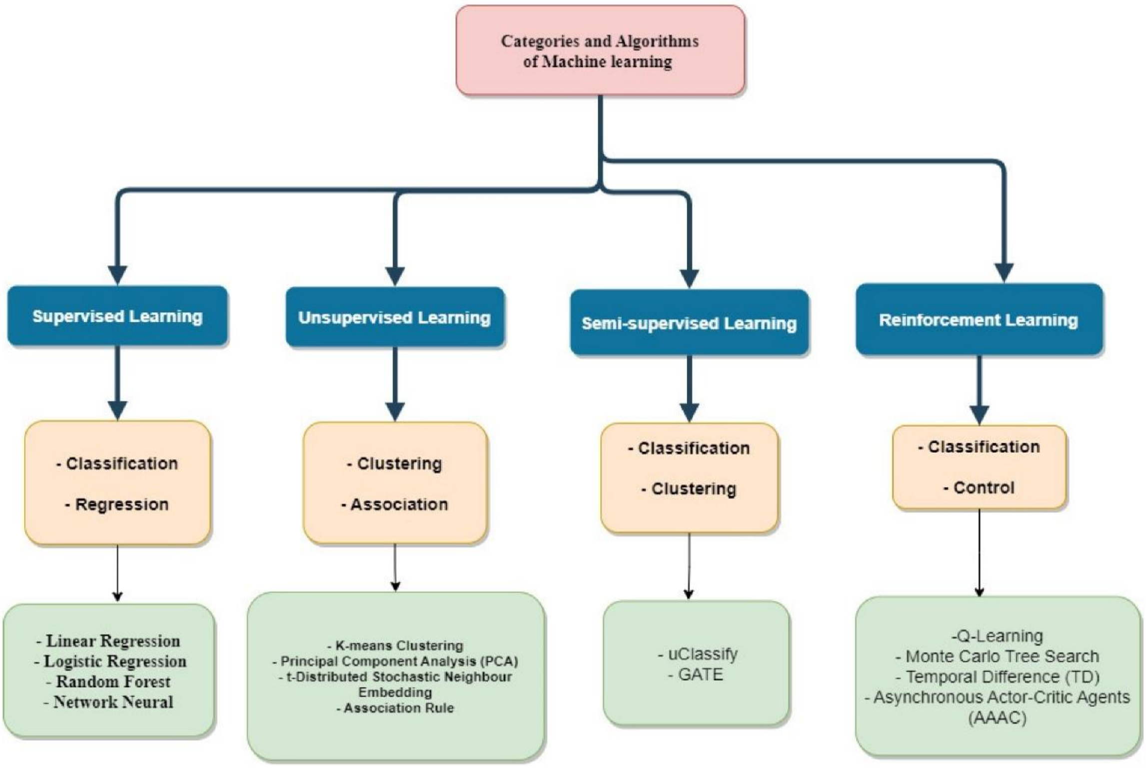


Figure 2.3: Different Machine Learning Categories and Algorithms [29]

2.4.1. Supervised Learning

Supervised learning is a kind of machine learning in which the algorithm is trained using a labeled dataset, implying that the output variable is already known. Using labeled data, the algorithm learns to map input to output [30].

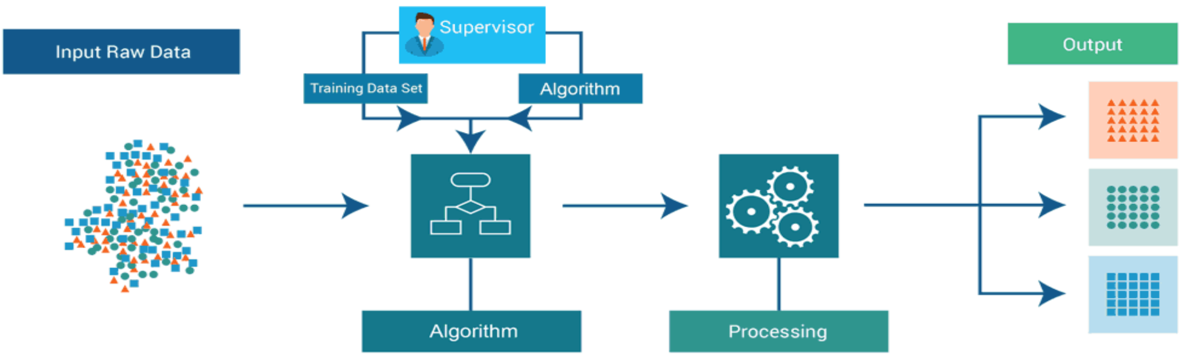


Figure 2.4: Supervised Learning [31]

2.4.2. Unsupervised Learning

Unsupervised learning is a kind of machine learning in which the algorithm is trained on unlabeled data, implying that the output variable is unknown. The algorithm identifies patterns and relationships in data by analyzing its fundamental structure [32].

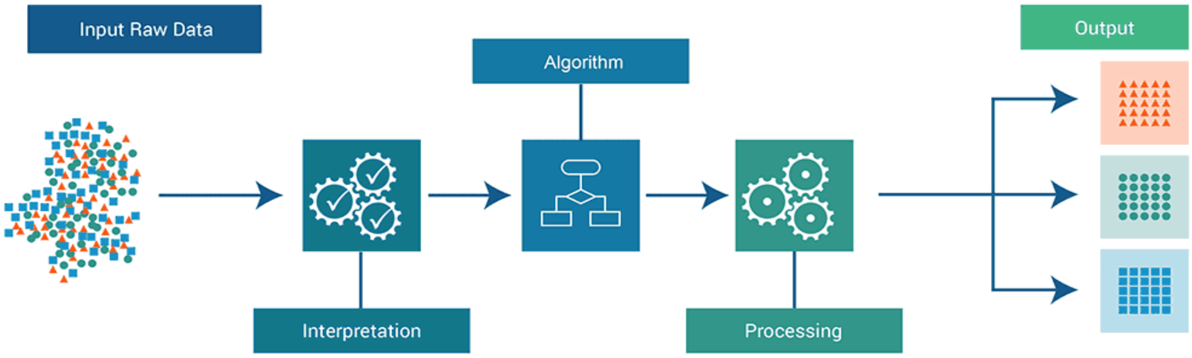


Figure 2.5: Unsupervised Learning [31]

2.4.3. Semi- supervised Learning

Semi-supervised learning is a kind of machine learning in which the algorithm is trained on both labeled and unlabeled datasets [33].

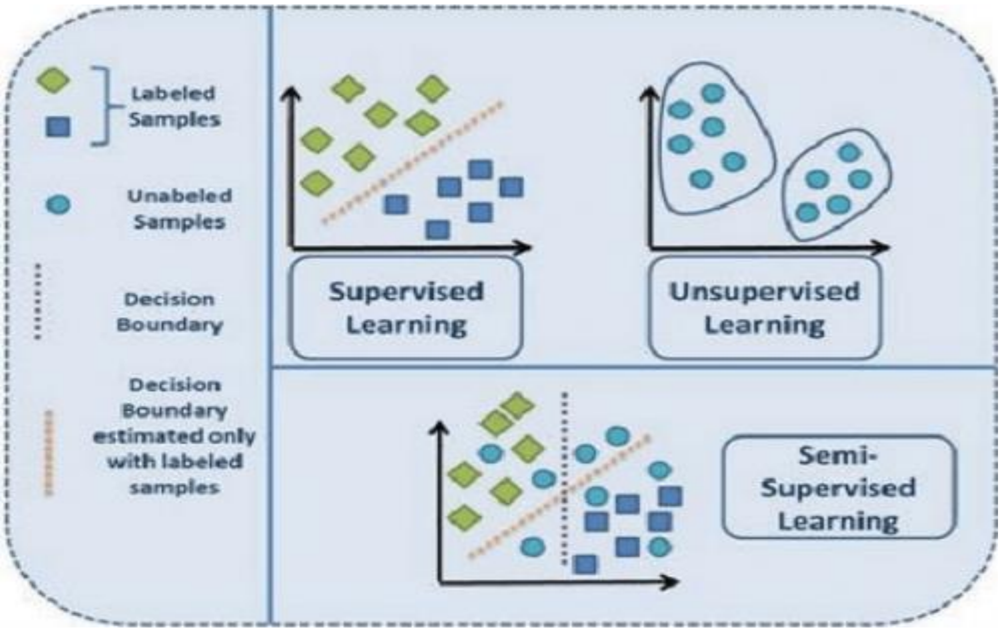


Figure 2.6: Semi-supervised Learning [34]

2.4.4. Reinforcement Learning

This type of machine learning involves rewarding or punishing algorithms based on their activities, in order to encourage it to make the correct decisions [35].

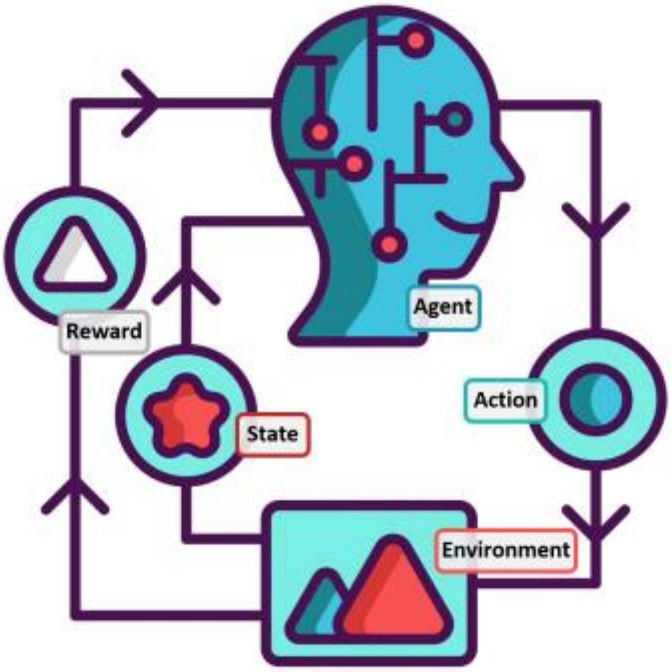
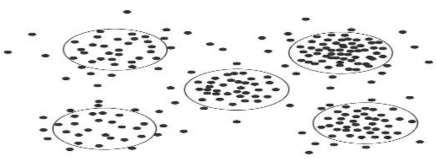
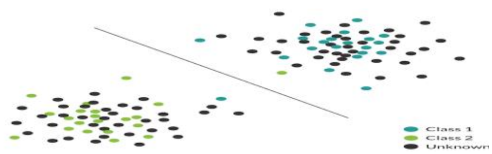


Figure 2.7: Reinforcement Learning [36]

2.4.5. Supervised vs Unsupervised Learning

In the table below, we've compared some of the key differences between unsupervised and supervised learning:

Table 2.1: Supervised vs Unsupervised

Supervised	**Unsupervised**
Input Data is labelled	Input Data is unlabeled
Uses training Dataset	Uses just input dataset
Data is classified based on training dataset	Uses properties of given data to classify it.
Used for prediction	Used for Analysis
Divided into two: types Regression and Classification	Divided into two :types Clustering and Association
Known number of classes	Unknown number of classes
	
Use of line analysis of data	Use Real time analysis of data

2.5. Applications of Machine Learning

- ***Speech Transcription***

  This means identifying spoken words and translating them to written text.

- ***Fraud Detection***

  Is the process of discovering fraudulent activity or transactions utilizing previous data and patterns.

- ***Image Classification***

  The goal is classifying images into different groups or categories using their distinguishing features**.**

- ***Recommender Systems***

  Can be used to develop recommendation systems, which suggest products or content to users according to their past interactions.

- ***Healthcare***

  Machine learning is used to diagnose diseases, predicted patient outcomes, create individualized treatment plans, discover new drugs, and analyze medical images.

2.6. Machine Learning Algorithms

2.6.1. Logistic Regression (LR)

Is a regression analysis technique that is often used for binary classification problems. It models the likelihood of a binary target variable (such as true/false, yes/no, or 0/1) based on one or more input variables. Logistic regression works by fitting a hypothesis function, typically a sigmoid function, to the input data, mapping each real-valued input to a value between 0 and 1, showing the probability of the positive class [37].

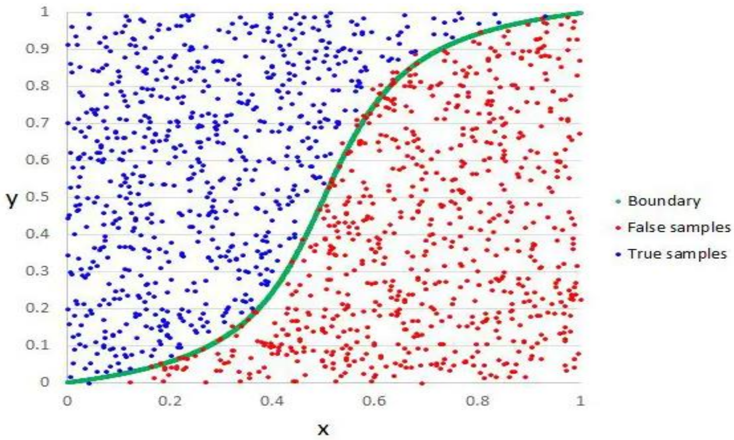


Figure 2.8: Logistic Regression Example [38]

2.6.2. Support Vector Machines (SVM)

SVM is a supervised learning technique that may be applied to both regression and classification. It distinguishes the classes and determines the appropriate hyperplane. Then, all of the classes are separated as well. It is widely used in applications including computer vision, natural language processing, recognition of speech, and picture recognition [39].

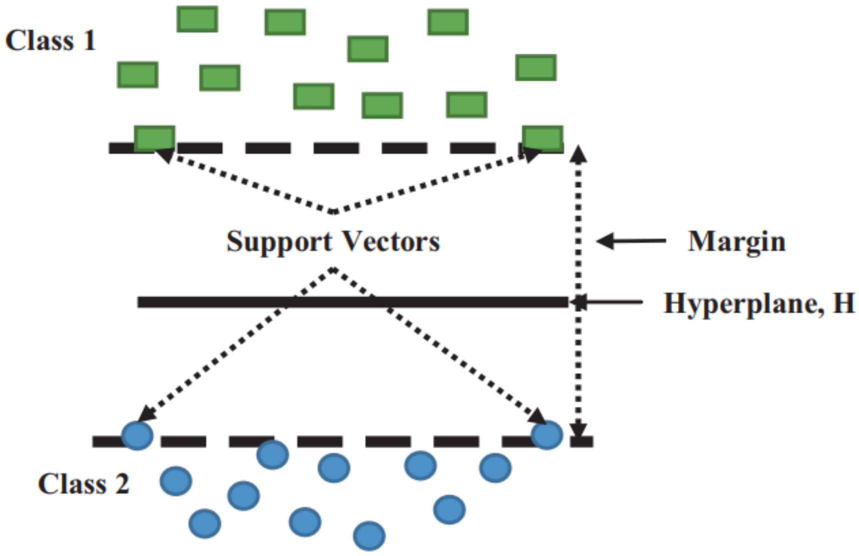


Figure 2.9: Working of SVM Algorithm [39]

2.6.3. Random Forest (RF)

Random Forest is a classifier that consists of an ensemble of tree classifiers with independent random vectors distributed in the same way, with each tree casting a single vote at entry x for the most popular class. A random vector independent of the previous random vectors of the same distribution is generated, as is a tree using the formation test. A higher bound is extracted for Random Forests to obtain the generalization error in terms of two parameters: accuracy and the interdependence of individual classifiers [40].

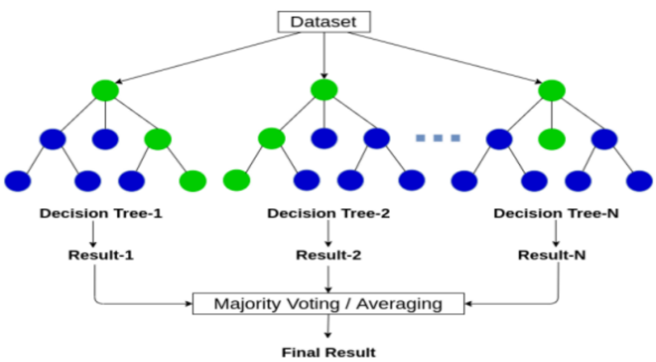


Figure 2.10: Random Forest Algorithm [40]

2.6.4. K-Nearest Neighbors (KNN)

Is a non-parametric classifier that may be applied to both classification and regression applications. It anticipates the result of a new data point using the k most comparable data points in the training set [41].

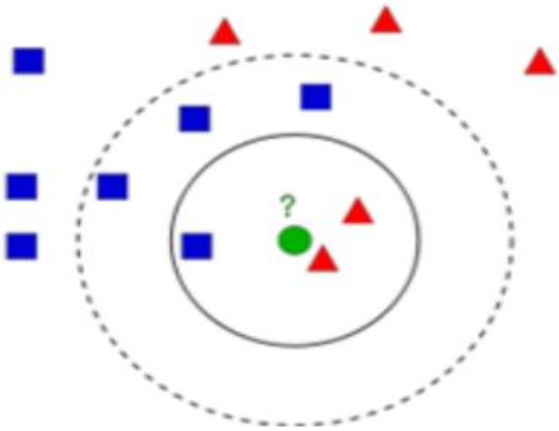


Figure 2.11: Classification of Query Image Through KNN Classifier [42]

2.7. Deep Learning

Deep learning is a branch of machine learning that use artificial neural network. Artificial neural networks consist of interconnected layers of neurons, which are capable of capturing complex relationships between data and solving complex problems including image and speech recognition, natural language processing, and games.

These networks can automatically learn and represent complex data properties, making them ideal for tasks requiring large amounts of data and complex interactions. called deep neural networks, to simulate the complex decision-making power of the human brain.

Deep Learning has been responsible for numerous advances in artificial intelligence in recent years, including the development of self-driving cars and the ability to defeat world champions in complex games such as Go. It has been useful in pharmacological research, genetics, and astrophysics [43].

Despite its numerous successes, Deep Learning still faces several problems, such as the necessity for vast volumes of data and the possibility of overfitting.

2.7.1. Artificial Neural Networks

An artificial neural network (ANN) is a fundamental building component of deep learning. It is a computational model that mimics the structure and functioning of a biological neuron. The neural network is composed of the input layer, hidden layer, and output layer:

- **The Input Layers**

Is the initial layer that receives data and transfers it to the model without performing any calculations.

- **Hidden Layers**

Refer to many interconnected layers that conduct mathematical operations on data and extract distinctive properties.

- **The Output Layer**

Is the final layer that produces the outcome by receiving inputs from the preceding hidden levels. [44]

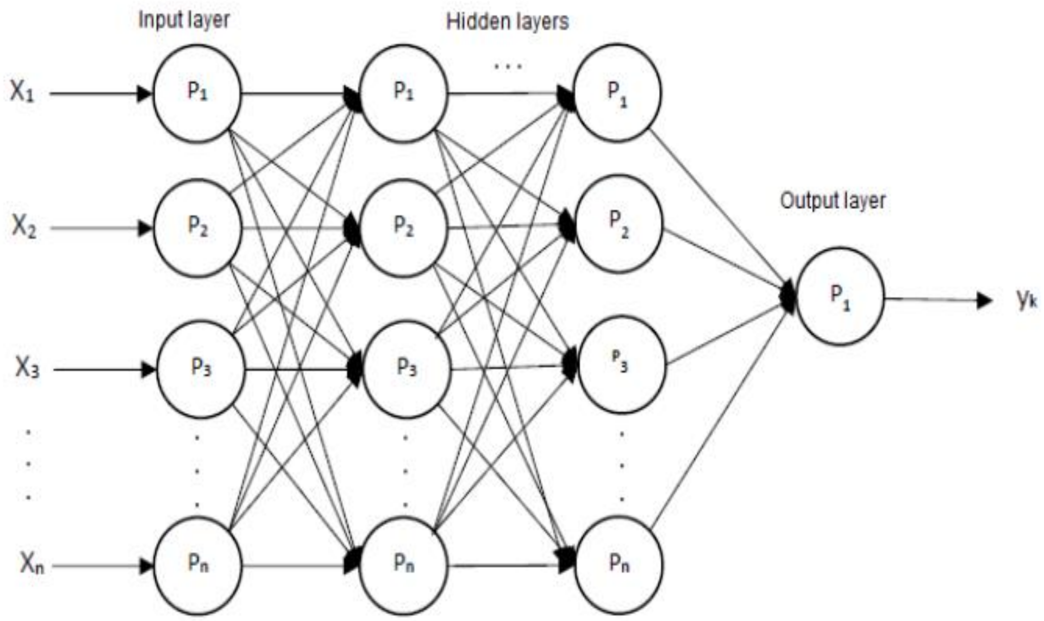


Figure 2.11: Structure of An Artificial Neural Network [45]

2.7.2. Artificial Neural Networks Types

There are several types of artificial neural networks, each of which has its advantages and disadvantages. In this subsection, we will mention the most famous ones and focus on the CNN model.

Here are some common types:

- **Deep Feed-Forward Neural Network (FNN)**

Feedforward neural networks (FNN) are one of the two primary types of network designs where information passes in a unidirectional manner, from the input layer to the output layer, without any feedback connections. A Feedforward Neural Network (FNN) is composed of many layers of interconnected neurons, which include an input layer, one or more hidden layers, and an output layer [46].

- **Convolutional Neural Network (CNN)**

CNNs, also known as ConvNets, are neural networks composed of multiple layers that are primarily utilized for image and video processing and pattern recognition.

Convolutional Neural Networks (CNNs) consist of multiple layers that are responsible for processing and extracting features from data:

Convolution Layer: Is consistently included as the initial layer. The primary goal is to detect the existence of a specific set of features in the input photos. In order to do this, it takes out a convolutional filtering process: this entails moving a window that represents the feature across the image and computing the convolutional product between the feature and each examined section of the image [47].

Rectified Linear Unit Layer (ReLU): A ReLU (Rectified Linear Unit) layer is a type of activation function commonly used in neural networks, particularly in deep learning models. It used to process elements and generate rectified feature maps as output [47].

Pooling Layer: A pooling layer is a key component in CNNs that reduces the spatial dimensions (width and height) of input feature maps. This reduction reduces the computing cost, the number of parameters, and the chance of overfitting.

Dense Layer: A completely connected layer is a sort of neural network layer in which each neuron is linked to every neuron in the preceding layer. This layer is often employed in feedforward neural networks and is required for the construction of many deep learning models, such as convolutional neural networks (CNNs) and recurrent neural networks (RNNs).

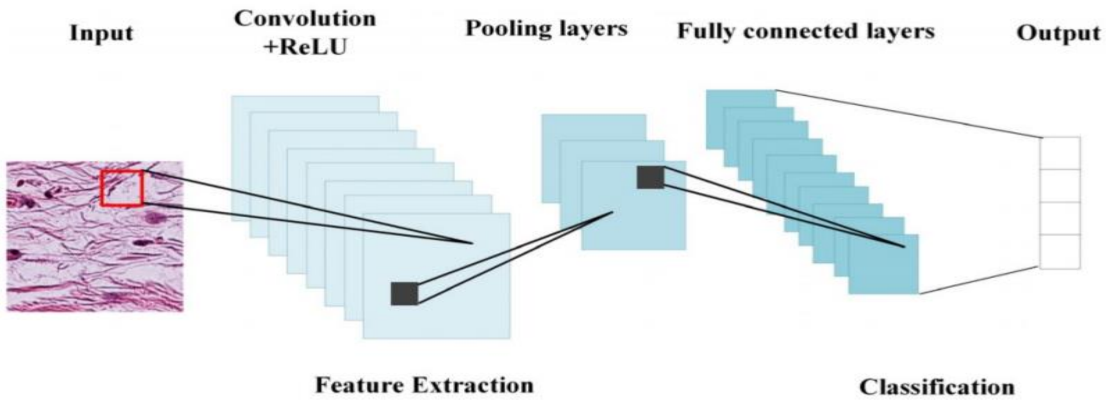


Figure 2.12: Convolutional Neural Network Architecture [48]

➢ **Deep Recurrent Neural Network (RNNs)**

Recurrent Neural Networks (RNNs) are a prevalent sort of Neural Network utilized in deep learning for tasks that deal with sequential input, such as natural language processing and speech recognition. They are defined by recurrence, specifically designed to capture the sequential patterns in the input data. They incorporate loops in their structure to enable the flow of information from one-time step to the next [28].

2.8. Applications of Deep Learning

DL has a wide array of applications across various fields, here are some prominent applications:

➢ ***Self-Driving Cars***

Also known as autonomous vehicles, rely on deep learning techniques for perception, decision-making, and control.

➢ ***Natural Language Processing (NLP)***

Deep learning has advanced NLP tasks such as language translation, sentiment analysis, text generation, question answering...

➢ ***Recommendation Systems***

Deep learning models are employed in recommendation engines to offer specific recommendations for products, movies, music, and other objects, taking into account user interests and behaviors.

➢ ***Image Classification***

Image classification has been greatly improved by the use of Deep Learning, particularly Convolutional Neural Networks (CNNs), which have demonstrated exceptional accuracy in the categorization of images. This innovative technology allows for the implementation of tasks like as object verification, analysis of medical images.

➢ ***Cybersecurity***

Deep Learning is capable of detecting advanced threats more effectively than traditional malware defense solutions. It uses a more proactive approach by identifying unknown suspicious activities rather than simply reacting to a database of known threats.

2.9. ML vs DL

Here are five main differences between machine learning and deep learning:

➢ ***Human Involvement***

Machine learning typically necessitates a greater degree of human involvement in order to achieve desired outcomes, whereas deep learning entails a more intricate initial setup but subsequently necessitates minimal interaction.

➢ ***Training Time***

Machine learning systems can be rapidly deployed and executed, but they may be constrained by their capabilities. Deep learning systems require a longer setup time, but they are capable of producing quick outcomes.

➢ ***Data Requirements***

Machine learning Demands reduced data usage while maintaining satisfactory outcomes. But in deep learning training models effectively necessitates large amounts of data.

➢ ***Hardware***

Machine learning applications may typically operate on standard computers and do not demand as much powerful hardware as deep learning algorithms. Deep learning algorithms, on the other hand, necessitate high-performance resources and commonly rely on GPUs because of their high memory and capacity to execute numerous tasks concurrently.

➢ ***Applications***

Machine learning is currently employed in common applications such as email, banking, as well as predictive maintenance. On the other hand, deep learning facilitates the development of more intricate and independent programs like self-driving automobiles, advanced surgical robots and computer vision.

2.10. Conclusion

In this chapter, we have discussed of basic notions such as AI, machine learning and deep learning. We talked about the different classifications of machine learning, including supervised learning, unsupervised learning, and reinforcement learning, and semi supervised learning. Also, we provide an overview about the applications and algorithms in this field. We give an overview of (CNNs), which are commonly used for image recognition and processing tasks, including convolutional layers, pooling layers, and fully connected layers and Rectified Linear Unit (ReLU).

CHAPTER 3

Implementation of the Proposed Solution

3.1. Introduction

In this chapter we will discuss about hardware and the used environment of work programming language and libraries, given description and preprocessing to our datasets to accomplish our goals that are used to build and train our model EfficientNetB3 and EfficientNetB5 and algorithms of ML which we used, and we make discussion about the results. Furthermore, we will showcase the interface application of the proposed model.

3.2. Hardware

During our project, we used two computers that have the following characteristics:

PC1

- ✓ Operating System: Windows 10 (64-bit)
- ✓ Central Processing Unit (CPU): Intel Core i5-7300U CPU @ 2.60GHz 2.71GHz.
- ✓ Random Access Memory (RAM): 8 .00GB
- ✓ Storage: C (237GB)
- ✓ Graphics Card: Intel(R) HD Graphics 620

PC2

- ✓ Operating System: Windows 10 Professional 64 bits
- ✓ Central Processing Unit (CPU): Intel(R) Core (TM) i3-1005G1 CPU @1.20GHz 1.19GHz
- ✓ Random Access Memory (RAM): 12.0GB
- ✓ Storage: 237 Go
- ✓ Graphics Card: Intel ® UHD Graphics

3.3. The Used Programming Language

3.3.1. Python

Python is a high-level programming language with dynamic semantics, ideal for rapid application development and scripting. Its simple syntax emphasizes readability, reduces maintenance costs, and supports modules and packages, encouraging code reuse. The Python interpreter and standard library are available for free distribution on major platforms [49].

3.4. Used Libraries

3.4.1. Numpy

Numerical Python (NumPy) is a Python library for scientific computing, offering multidimensional array objects, derived objects, and routines for fast operations on arrays, including mathematical, logical, and statistical operations [50].

3.4.2. Pandas

Python Data Analysis Library (Pandas) is fast, powerful, flexible tool, and an open-source Python library used for managing structured data, particularly tabular data like spreadsheets and relational databases, in data science and analytics workflows [51].

3.4.3. Keras

Key Enabling Rapid Applicability System (Keras) is a Python library that is built on top of the high-level API of the TensorFlow platform. The interface offered by this system is easy to use and efficient for solving machine learning (ML) challenges, particularly those related to current deep learning. Keras encompasses data preprocessing to hyperparameter optimization to deployment. The development process prioritized facilitating rapid experimentation [52].

3.4.4. TensorFlow

TensorFlow is an open-source machine learning library that has been developed by Google. TensorFlow enables developers to build and train diverse machine learning models for applications such as classification, regression, and clustering. TensorFlow is used for constructing and training deep learning models due to its ability to simplify the development of computational graphs and optimize execution on diverse hardware platforms. TensorFlow is utilized in applications that involve text analysis, recognizing images, and voice-based search [53].

3.4.5. OpenCV

Open Source Computer Vision (OpenCV) is a software library that focuses on computer vision and machine learning. It is open source, meaning that its source code is freely available for anyone to use and modify. OpenCV was developed with the purpose of provide a common infrastructure for computer vision applications and to accelerate the use of machine perception in the commercial products [54].

3.4.6. Matplotlib

MATLAB Plotting Library (Matplotlib) is a Python-based open-source plotting library that offers various functions for creating static, interactive, and animated visualizations in Python.It's highly customizable, integrates with other libraries like NumPy and Pandas, making it a versatile tool for data analysis and visualization. Matplotlib makes easy things easy and hard things possible[55].

3.4.7. Tkinter

Tkinter is a standard GUI (Graphical User Interface) toolkit included with Python for creating desktop applications. It provides a collection of modules and classes for creating windows, buttons, menus, text boxes, enabling developers to design interactive user interfaces [56].

3.4.8. OS

The os module is an integral component of the Python standard library, offering a platform-independent means of interacting with the operating system. The software provides capabilities for executing diverse operating system operations, including tasks like manipulating files and directories, managing environment variables, and controlling processes.

3.4.9. Scikit-learn

Scientific Kit for Machine Learning (Scikit-learn) is Python library for machine learning that is developed using NumPy, SciPy, and Matplotlib. The software offers effective techniques for extracting valuable information from data and analyzing it. These capabilities include classification, regression, clustering, and dimensionality reduction, all accessible through a user-friendly interface. Scikit-learn is extensively utilized in both academic and industrial settings, and it stands as one of the most prevalent Python libraries for machine learning [57].

3.4.10. Pillow

Pil is a Python library for opening, manipulating, and saving image file formats like JPEG, PNG, and GIF. It supports common processing tasks and integrates with NumPy for efficient array-based manipulation, making it essential for Python developers. Known for its ease of installation and use, Pillow is a vital tool for developers needing robust image processing capabilities in their Python projects.

3.4.11. CustomTkinter

CustomTkinter is an enhanced generation of the conventional Tkinter library in Python, offering modern-looking widgets and additional features for building graphical user interfaces (GUIs), The software offers the ability to create personalized themes and has updated graphical elements such as buttons, labels, and input fields.

3.5. Working Environment

3.5.1. Kaggle

Kaggle is an online platform for data scientists and machine learning enthusiasts to explore, share, and compete with data analysis and modeling projects, offering a diverse range of datasets in various formats (CSV, JSON, SQL, and more), serving as a hub for learning, collaboration with others, and fast innovation in the fields of data science and machine learning.

3.5.2. Anaconda

Anaconda is a free, open-source Python and R distribution, simplifying package management and deployment. It includes Jupyter Notebook, Spyder IDLE, and data science libraries like NumPy, Pandas, Scikit-learn, TensorFlow, and OS. Anaconda's Python interpreter and machine learning packages are housed in an environment, a curated directory allowing for separate package maintenance and execution without interference.

3.5.3. Jupyter NoteBook

Jupyter Notebook is an open-source web application that allows users to create and share and distribute documents containing live code, equations, visualizations, and narrative text. Uses for data cleaning and transformation and manipulation, numerical simulation, statistical modeling, data visualization, machine learning and various other tasks.

3.5.4. Google Colab

Practicing on projects becomes a constraint since you need high-end PCs for such workloads, the answer to this issue is Google Colab, or Collaboratory is a cloud-hosted version of Jupyter Notebook, to use Colab, you do not need to install and runtime or upgrade your computer hardware to meet Python’s CPU/GPU intensive workload requirements .Colab allows you to write and execute Python in your browser, with Zero configuration required, access to GPUs free of charge. Google Colab makes data science, deep learning, and neural network, and machine learning accessible to individual researchers who cannot afford costly computational infrastructure.

3.5.5. Vs Code

Visual Studio Code (VS Code) is a free, open-source code editor developed by Microsoft that has become a popular tool among developers for its versatility and powerful features. Designed for the development and debugging of modern web and cloud applications, VS Code offers a highly customizable environment where users can tailor themes, keyboard shortcuts, and preferences to their specific needs. It supports a wide range of programming languages through built-in features and an extensive marketplace of extensions, enhancing its functionality for various development tasks.

3.6. Datasets

3.6.1. Datasets Description

We found the datasets on Kaggle. This dataset consists of anonymized and no identified panoramic dental X-rays, taken at Noor Medical Imaging Center, Qom, Iran [58]. The images were manually classified by a dental clinic into two classes.

- Number of Images: The dataset contains a total 212.
- Classes: there are two categories, the first category (infected) has 158 images, and the second one is (not infected) has 54 images (Figure 3.1 and Figure 3.2).
- labels: yes =1 infected, no =0 not infected.

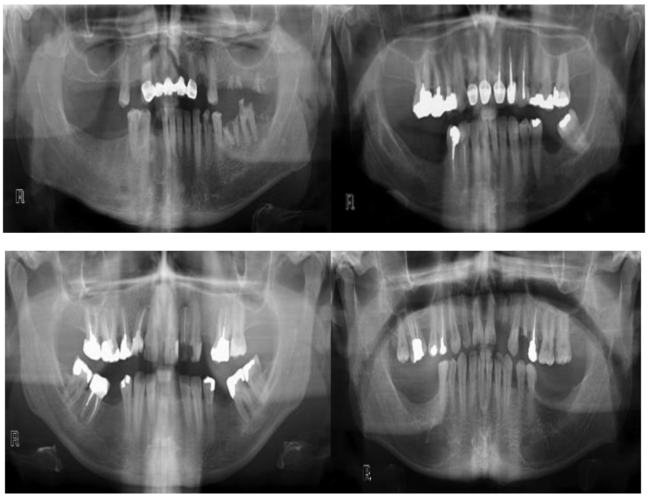


Figure 3.1: Examples of Infected Images Issued of The Used Dataset

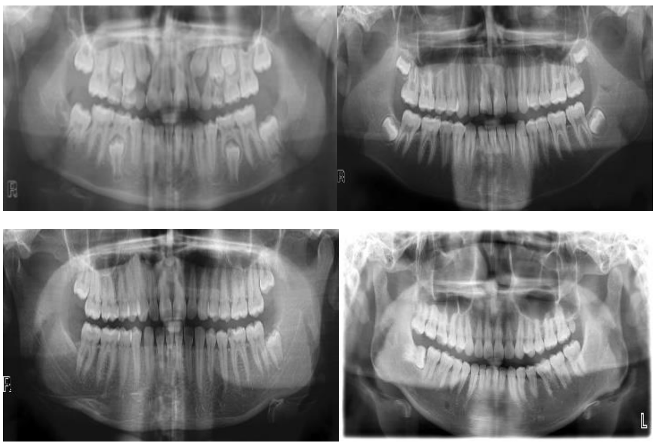


Figure 3.2: Examples of Not Infected Images Issued of The Used Dataset

3.6.2. Data Preprocessing

To prepare the dataset for the training process, we applied some preprocessing tasks which are:

- **Image cropping:** focuses on the mandible (lower jaw) and maxilla (upper jaw) area. It involves converting an image's color to a grayscale color, and applying an average blur to this grayscale image to reduce noise while preserving important edges and thresholds. This results in a blurred image that distinguishes the teeth from the background.
- **Image resizing:** It consists of resizing the image to a specific size (224,224) to deal with the requirements of the model.
- **Normalization:** normalize the image pixel values by dividing by 255 to bring them into the range [0, 1].
- **Data partitioning*:*** It consists of dividing the data set into training (80%), testing (20%), and validation (10%) sets to accurately evaluate the model's performance.

3.6.3. Dataset Augmentation (Specific Preprocessing Task)

To enhance the training dataset, we implemented several data augmentation techniques. These included rotating images randomly by up to 10 degrees, shifting them horizontally and vertically by up to 10% of their dimensions, applying shear transformations with an intensity of 0.1, adjusting brightness within a range of 0.3 to 1.0, and randomly flipping images both horizontally and vertically. To fill newly created pixels during transformations, we utilized the 'nearest' fill mode, ensuring image integrity. These techniques effectively expanded the dataset, introducing variations in object orientation, position, lighting, and shape, thereby increasing the model's robustness to real-world variations and preventing overfitting.

The table 3.1 below shows the numbers of images before and after augmentation:

Table 3.1: Number of Datasets After Augmentation

Classes	Original Images	Augmented Image
Infected	158	1263
Not infected	54	564

3.7. Frequently Used Models

Among the most widely used models there is EfficientNet family.

EfficientNet, first introduced in Tan and Le (researchers at Google AI), 2019 is among the most efficient models that reaches cutting-edge accuracy on both ImageNet and common image classification transfer learning tasks [59].

EfficientNet is a family of convolutional neural networks (CNNs), The key idea behind EfficientNet is a compound scaling method that uniformly scales the depth, width, and resolution of the network using a compound coefficient, which allows for better performance with fewer computational resources. Compound scaling it mean EfficientNet's scaling method adjusts all dimensions (depth, width, and resolution) of the network simultaneously, rather than scaling them independently. This leads to more balanced and efficient models [59].

The EfficientNet models range from B0 to B7, with each subsequent model increasing in size and computational complexity, among these models we have used in our topic:

3.7.1. EfficientNetB3

EfficientNetB3 is a convolutional neural network (CNN) from the efficient family. it uses a compound model scaling method. EfficientNetB3 has 12 million parameters and achieves an accuracy of 81.1% on ImageNet. It features a 1.4 multiplier for both depth and width. The input size is 300x300x3, and it comprises of 24 convolution layers [59], as shown in Figure 3.3:

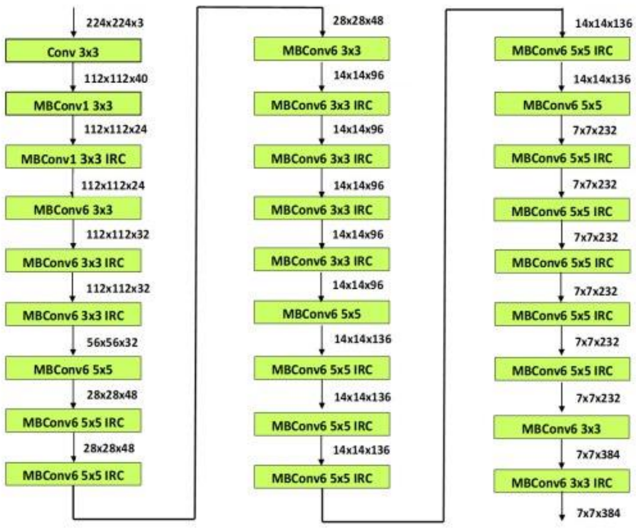


Figure 3.3: Architecture of EfficientNetB3 Model [60]

3.7.2. EfficientNetB5

EfficientNetB5 is a convolutional neural network (CNN) from the Efficient family that employs a compound model scaling approach. It has 30 million parameters and is 83.3% accurate on ImageNet. It has a depth multiplier of 2.2 and a width multiply of 2.0. The input size is 456x456x3, and it comprises of 40 convolution layers [59], as shown in the figure 3.4:

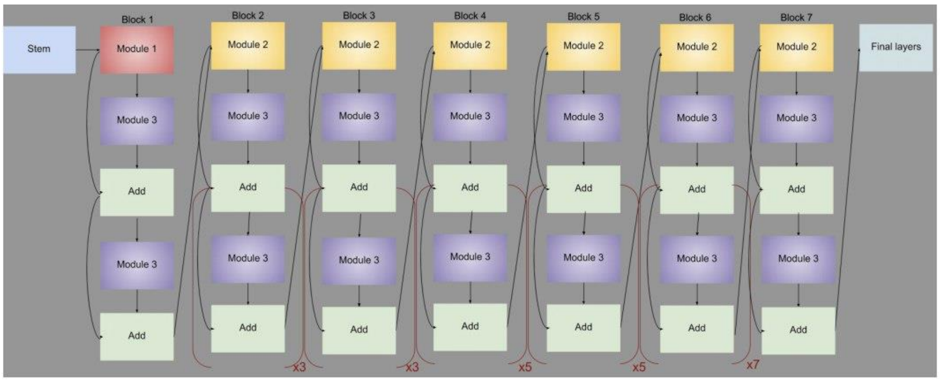


Figure 3.4: Architecture of EfficientNetB5 Model [59]

3.8. The Proposed Models

Transferring knowledge from one expert to another is known as transfer learning. In deep learning techniques, this approach is used where the CNN is trained on the base dataset (source domain), which has a large number of samples (e.g., ImageNet). Then, the weights of the convolutional layers are transferred to the new small dataset (target domain). Using pretrained models for classification tasks can be divided into two main scenarios: freezing the layers of the pretrained model and fine-tuning the models.

3.8.1. The First Model

- **Building the DL Model**

For the first proposed model , we used a pretrained EfficientnetB3 model as a base model with imagenet weights and excludes the top layers .and we added a sevral layers on top of it fine tuning. The added layers include a **Global Average Pooling layer**, this layer replaces the fully connected layers at the top of base model with a Global Average Pooling operation. the motivation behind using this layer is to generate a single feature map for each infected and not infected category of the classification task .Then, we added **Dense layer** with **Relu Activation function**, this layer have 512 neurons to learn complex patterns. Also, for prevent **Overfitting**, we added a Dropout layer with a rate of 0.2 (randomly drops out 20% of neurons in the previous layer during training) after Dense layer. Finally, we added a second **Dense** layer with a single unit and a **Sigmoid activation function,** this layer outputs a probability value between 0 and 1 was configured for our binary classification task ,see the figure 3.5 and table 3.2 below :

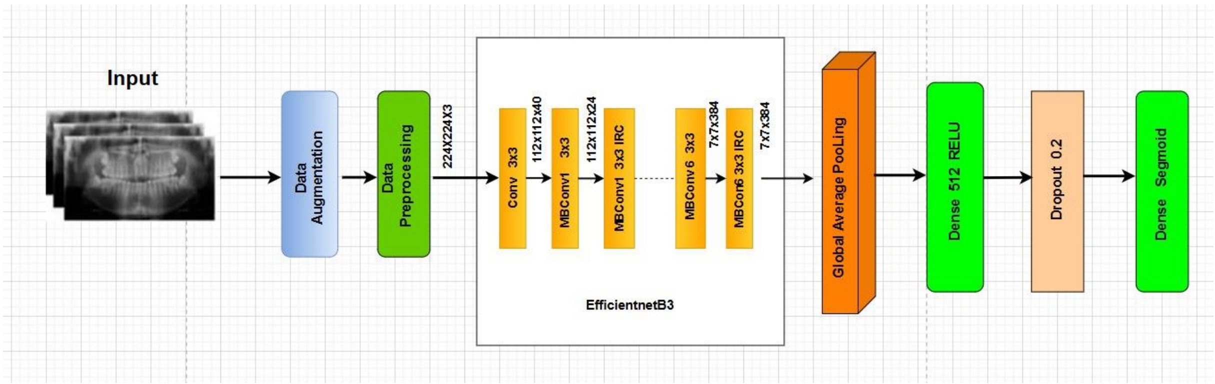


Figure 3.5: Architecture of The First Proposed Model

Table 3.2: Architecture the Proposed Model EfficientNeB3

Layer (type)	**Output shape**	**Parameter**	**Connected to**
GlobalAveragePooling2D	(None,1563)	0	Top activation
Dense_3 (dense)	(none,512)	786,944	GlobalAveragePooling2D
Dropout_2(dropout)	(none,512)	0	Dense_3[0][0]
Dense_4(dense)	(none,1)	513	Dropout_2[0][0]

- ### Train the Model

For training step, the model is compiled with the Binary_Crossentropy loss as function and RMSprop optimizer with a learning rate of 0.0001 and accuracy as the evaluation metrics and training is conducted on the provided training data with validation data for performance monitoring, over 30 epochs with a batch size of 16 and utilizing ReduceLROnPlateau and EarlyStopping callbacks. ReduceLROnPlateau with a patience of 2 and EarlyStopping was used with a patience of 6 to optimizing learning rates dynamically, prevent overfitting and restore the best weights.

- ### The Obtained Results

In this proposed model, we have achieved an accuracy of 98.387% for the test set. The table below shows clearly the obtained results.

Table 3.3: Obtained Results of First Model

Accuracy test	**Loss test**	**Precision test**	**Recall test**
98.3871	0.0575	0.984	0.984

The performance or the effectiveness of the model was evaluated using two main metrics accuracy and loss. The training and validation accuracy were plotted over the number of epochs to provide an overview of the model's performance during training. Similarly, the training and validation loss were also plotted over the number of epochs to assess the model's ability to minimize the loss function.

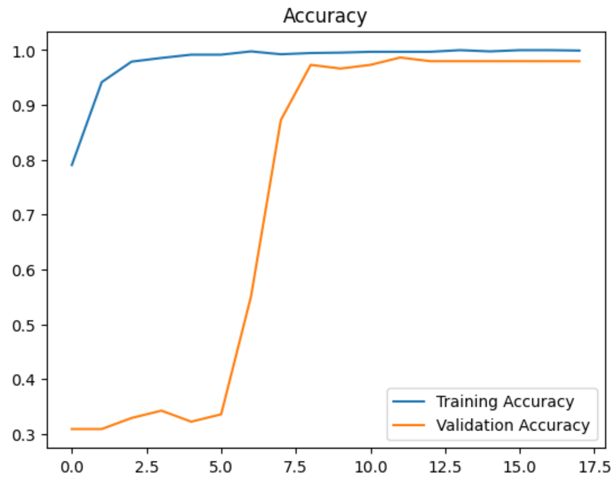


Figure 3.6: Training and Validation Accuracy

The graph represents accuracy of our model aver 30 epochs. The training accuracy indicate the percentage of correctly predicted instances out of all training instances, while the validation accuracy is the measure of how well the model performance on a validation dataset that was not used during training.

During the training phase the model shows significant accuracy starting from 71% in epoch 1 and reaching 99,24% by epoch 6 and maintaining high values in subsequent epochs. Similarly, in validation phase the validation accuracy started from lower accuracy of 30,87% at the first epoch, than shows fluctuation at early epochs to the epoch 8 which start showing significant improvement with 87,25% accuracy and maintaining high values in subsequent epochs.

Training concludes with early stopping at epoch 18 in this epoch the model achieves a high accuracy of 99,95% with high validation accuracy of 97,99%.

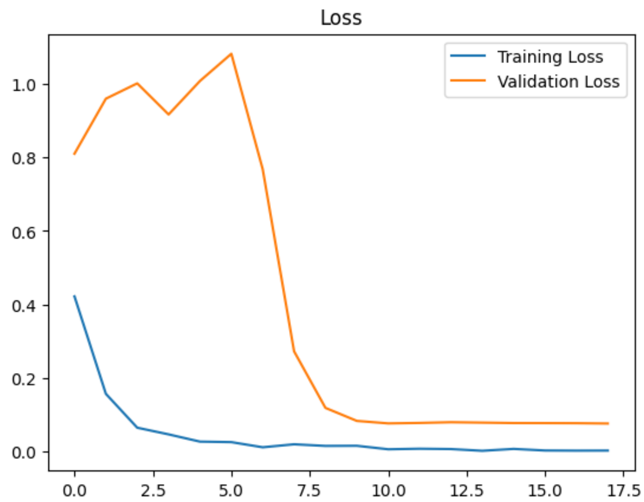


Figure 3.7: Training and Validation Loss

The graph illustrates the training and validation loss of the proposed model over 18 epochs. Both training loss and validation loss represent the measure of error between the model's predictions and the true values on the training data and validation data, respectively.

During training, the training loss decreases substantially from 0.5176 in the first epoch to 0.0236 by epoch 6 and continues to decrease in subsequent epochs, demonstrating the model's effective learning from the training data.

In the validation phase, the validation loss starts relatively high at 0.8098 in the first epoch but decreases over time, particularly after epoch 7 onwards. This trend indicates improved model robustness and generalization capability.

After early stopping at epoch 18, the model achieves a low training loss of 0.0021 and a validation loss of 0.0763, indicating that the model has learned well from the training data and generalizes effectively to new unseen data.

3.8.2. The Second Model

- **Building the DL Model**

The second proposed model, we used a pretrained EfficientNetB5 model as a base and added several layers on top of it for fine-tuning. The added layers include: **a Global Average Pooling2D** layer, followed by **a dense layer with 512 units and ReLU activation**, **a dropout layer with a 0.2 rate**, and **another dense layer with a single unit** and **sigmoid activation function** as a final layer . The figure below explains the architecture in more detail.

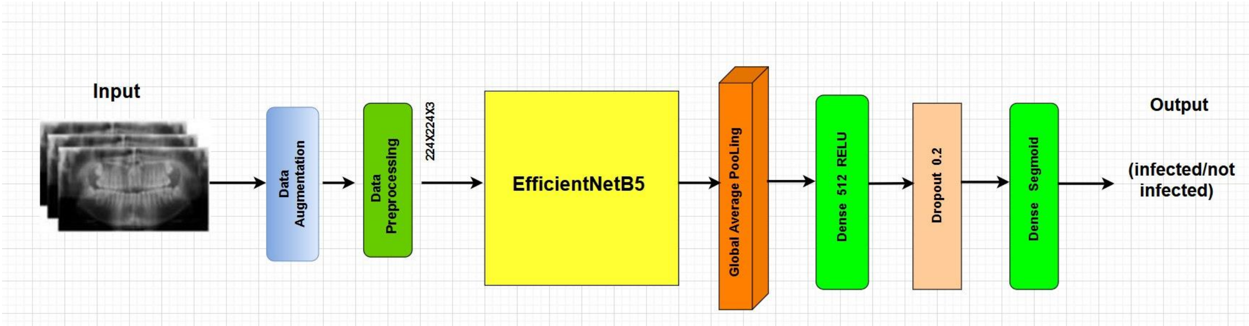


Figure 3.8: Architecture of Second Proposed Model

Table 3.4: Architecture of Seconde Proposed Model

Layer (type)	**Output shape**	**Parameter**	**Connected to**
GlobalAveragePooling2D	(None,2048)	0	Top activation
Dense_7(Dense)	(None,512)	1,049,088	GlobalAveragePooling2D
Dropout_4(Drouptout)	(None,512)	0	Dense_7[0][0]
Dense_8(Dense)	(None,1)	513	Dropout_4[0][0]

➢ Train the Model

For the training step, we compiled the model with binary cross-entropy as the loss function and optimized it using the RMSprop optimizer with a learning rate of 0.0001. Accuracy was used as the evaluation metric. Training was conducted on the provided training and validation data for performance monitoring, over 30 epochs with a batch size of 16, utilizing ReduceLROnPlateau with a patience of 2 and EarlyStopping with a patience of 6 callbacks.

➢ The Obtained Results

With this proposed model, we achieved an accuracy of 97.31% on the test set. The table 3.5 below clearly shows the obtained results.

Table 3.5: Obtained Results of Second Model

Accuracy test	**Loss test**	**Precision test**	**Recall test**
97.3118	0.07839	0.974	0.973

The performance of this model was evaluated using two main metrics: accuracy and loss. The figures below show the accuracy and the loss values obtained by this proposed model.

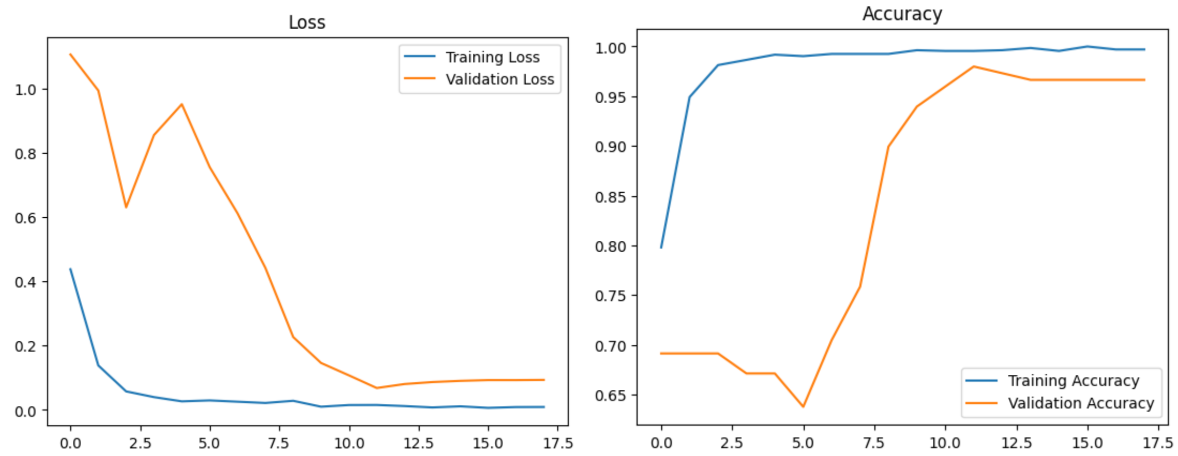


Figure 3.9: Training and Validation Loss and Accuracy

3.8.3. Model Evaluation

Accuracy: A metric employed to assess the effectiveness of a classification model's performance. It represents the ratio of accurately classified occurrences to the total number of instances. Accuracy is a metric used to assess the effectiveness of a classification model. It represents the ratio of accurately classified occurrences to the total number of instances [61]. Accuracy is typically calculated using the following equation:

$$Accuracy = \frac{\text{Number of correctly classified instances}}{Total\ number\ of\ instances}$$

Loss: Loss is a measure of how well or poorly a model's predictions match the actual outcomes in training data. Loss functions quantify the difference between predicted and actual values [62].

$$\text{Loss} = \frac{1}{N}\sum_{i=1}^{n}(\,y_i - \overline{y}_i)^2$$

Precision: also known as confidence in data mining, refers to the fraction of predicted positive cases that are actually real positives. It measures how many of the items identified as positive are truly positive [63].

$$\text{Precision} = \frac{True\ positive}{True\ Positives + False\ Positives}$$

Recall: Recall (Sensitivity)Recall refers to the fraction of real positive cases that are accurately predicted as positive. It measures how well the model identifies all the actual positives [63].

3.9. Comparison Between Used Models

We compared the performance of different machine learning algorithms such us Random Forest, K-Nearest Neighbors (KNN), Support Vector Machine (SVM), Logistic Regression (LR) and deep learning models (EfficientnetB3 and EfficientnetB5) that we used for binary classification diagnosis of dental state based on their accuracy. The table 3.6 below, shows the accuracy values achieved by each of machine learning algorithms and deep learning models

Table 3.6: Comparison Between Used Models

Algorithm	**Accuracy**
LR	66.2 %
SVM	65. 1%
KNN	69.7%
RF	77.3%
EfficientNetB3	**98.387%**
EfficientNetB5	97.311%

Among the machine learning algorithms, Random forest achieved the highest accuracy of 77% mean that this algorithm is able to correctly classify 77% of the instances of the dataset, followed by KNN algorithm with 69% accuracy, logistic regression (LR) with 66% accuracy, and support vector machine with 65% accuracy which represents the lowest accuracy in comparison with previous algorithms.

And among the deep learning models EfficientNetB3 achieved the highest accuracy among all models with 98.387%, and EfficientNetB5 also performed very well with 97.311% accuracy.

In summary, while traditional machine learning algorithms provide reasonable accuracy levels, deep learning models (EfficientnetB3 and EfficientnetB5) achieved a perfect accuracy especially EfficientnetB3. These indicate the effectiveness of deep learning architectures such us EfficientNet in dealing with complex image data and achieving high predictive accuracy.

Based on the obtained results from the two proposed models, we choose the first proposed model to implement in our system.

3.10. Application Interface

3.10.1. Login Page

The login page is designed to implement security measures for the application. Users enter their username and password, then press the login button. If there is an error, the application displays a message box to inform the user of the issue. Otherwise, the user is taken to the home page. New users can create an account by clicking on the sign-up button.

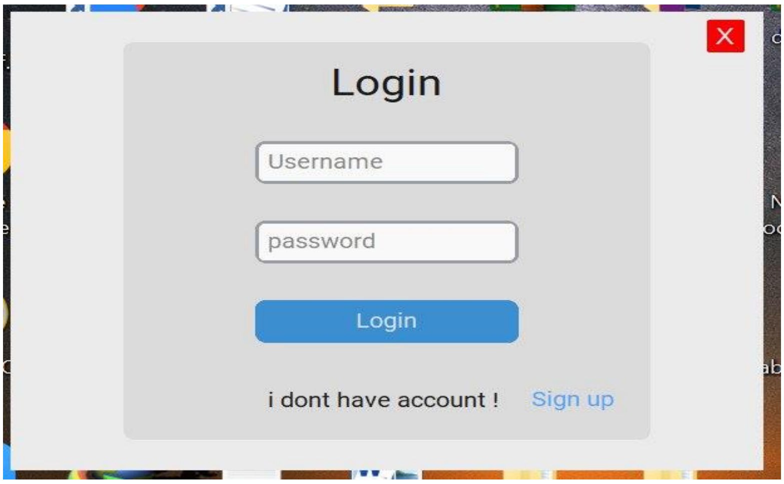


Figure 3.10: Login Page

3.10.2. Registration Page

The new user enters a username and password and confirms password. After pressing the sign-up button, if the password and confirmation password do not match, the application displays a message box to inform the user that the confirmation password is incorrect. The sign-up page includes also a button to return to the login page.

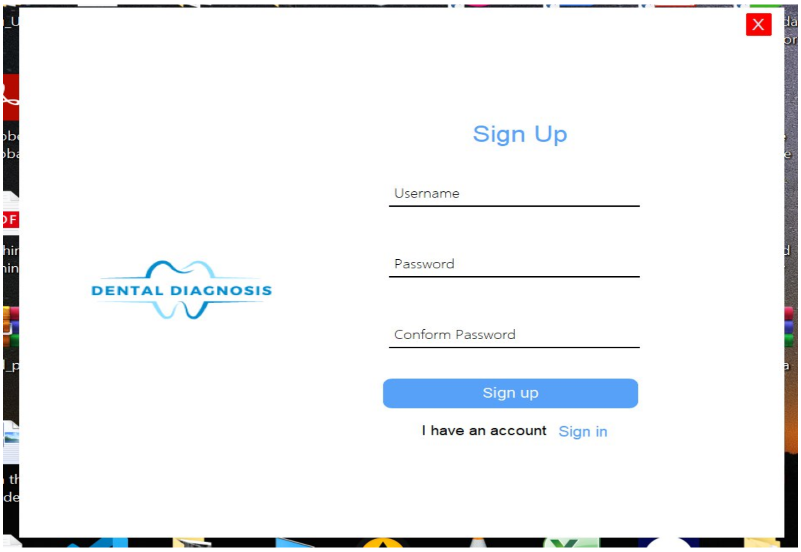


Figure 3.11: Registration Page

3.10.3. Diagnosis Page

This page allows the user to make a diagnosis by clicking on the open image or open folder button and load one panoramic radiograph image or a folder of panoramic radiographs, then pressing the **SinglePred** button or **MultiPred**, and the result appears on the opposite side as a single or multiple infected or not infected cases. The user can also see more Information about the model by clicking on **More information** such as accuracy graph, loss.

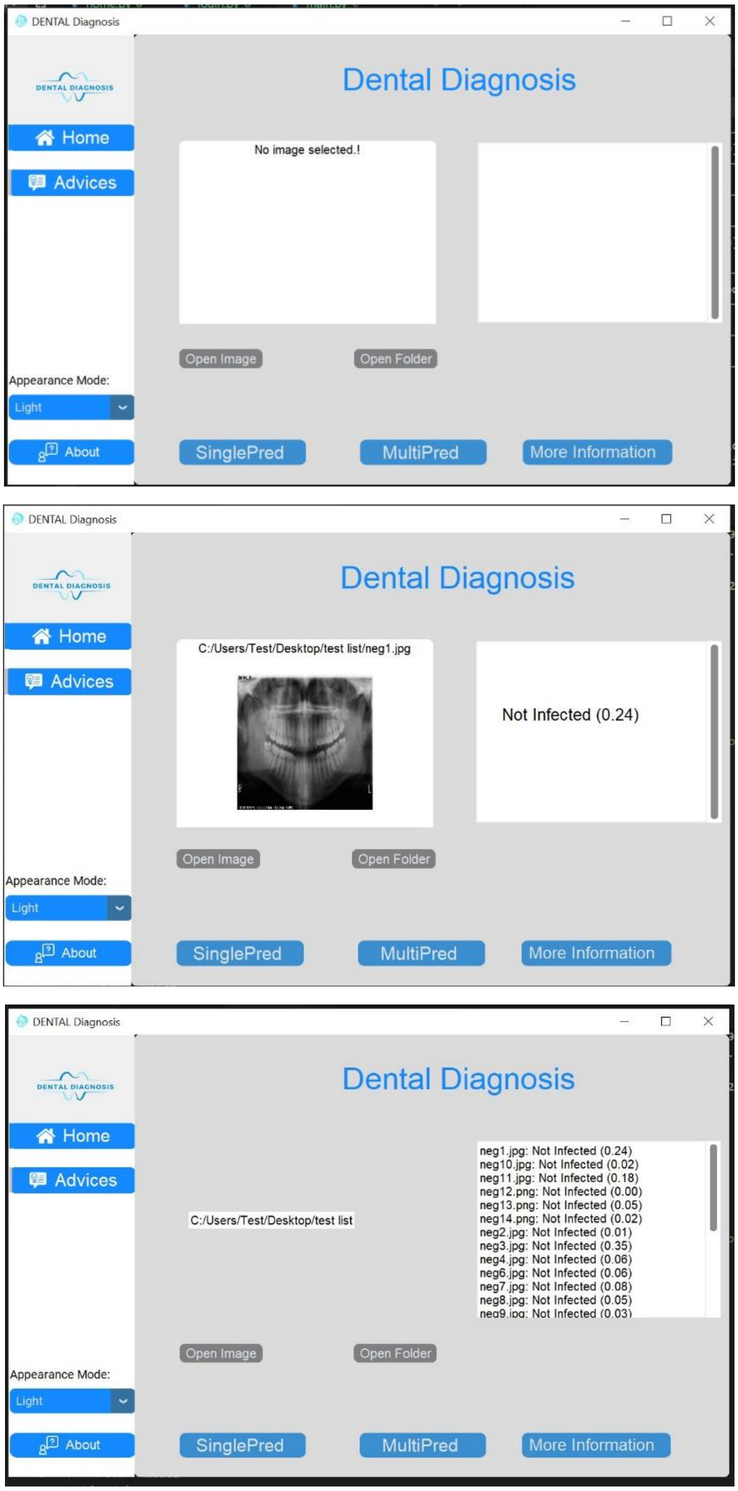


Figure 3.12: Diagnosis Page

3.10.4. About Our Application Page

This page "***About our Application***" gives an overview and comprehensive description of our application and its purpose and our future goal is to expand the system and make it capable of extracting all pathologies from panoramic radiography.

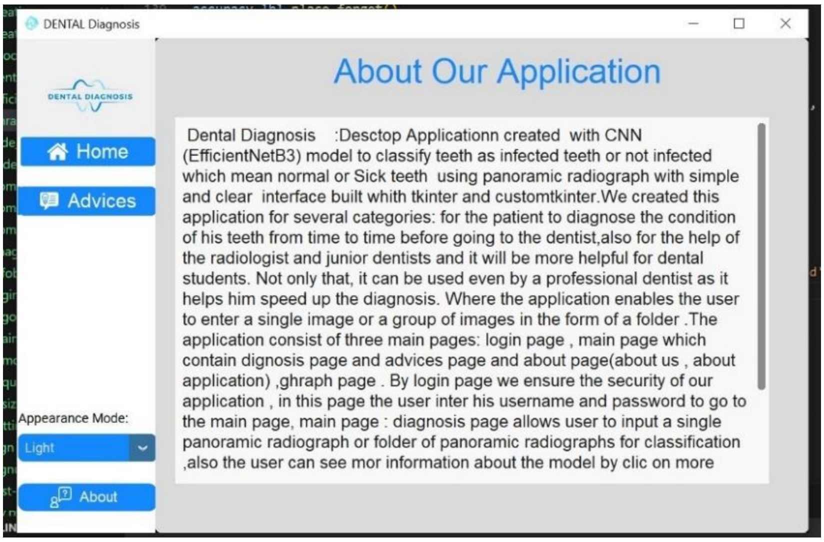


Figure 3.13: About Application Page

3.10.5. Advices Page

This page contains a set of advices provided, such as: regular brushing, visiting dentist periodically, don't smoking, ...

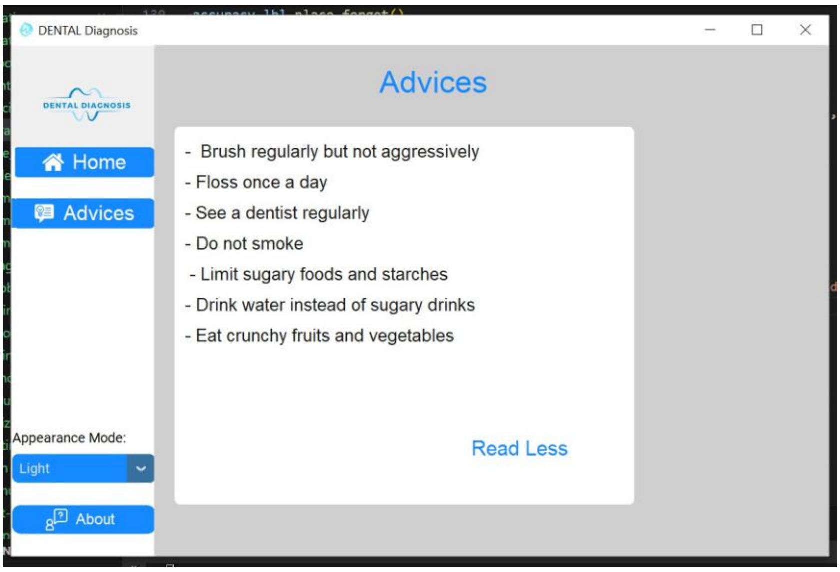


Figure 3.14: Advices Page

3.10.6. About us Page

This page provides an overview of the creators of the application. It includes: creators 'information, supervisor's information, university details, information sources, an email address for contact in case of questions or inquiries.

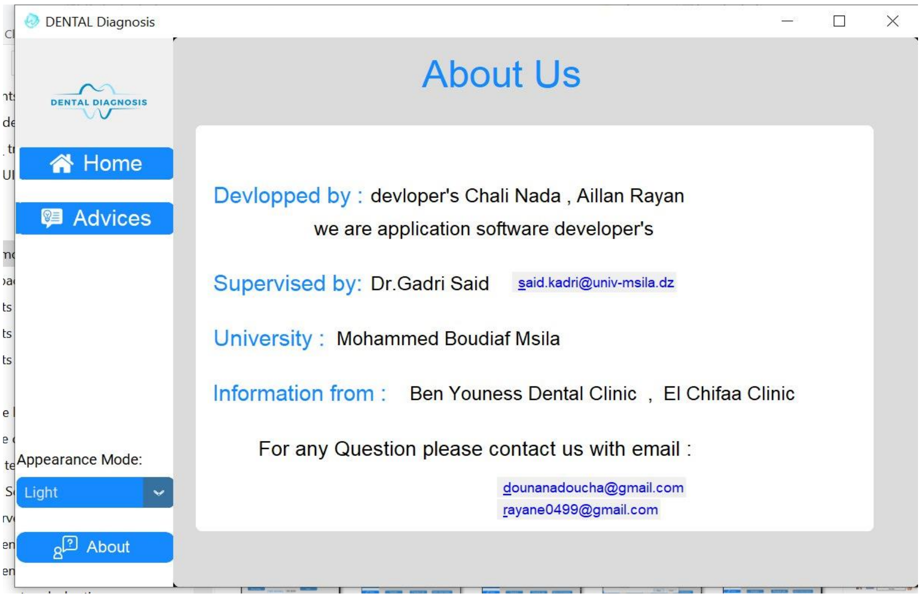


Figure 3.15: About us Page

3.10.7. Information Page

This page is designed to visualize the performance of the model and appears when the user clicks on the "More Information" button. It includes: the accuracy graph, the loss graph, the values of accuracy (for both training and testing), as well as a back button to go back to the main page.

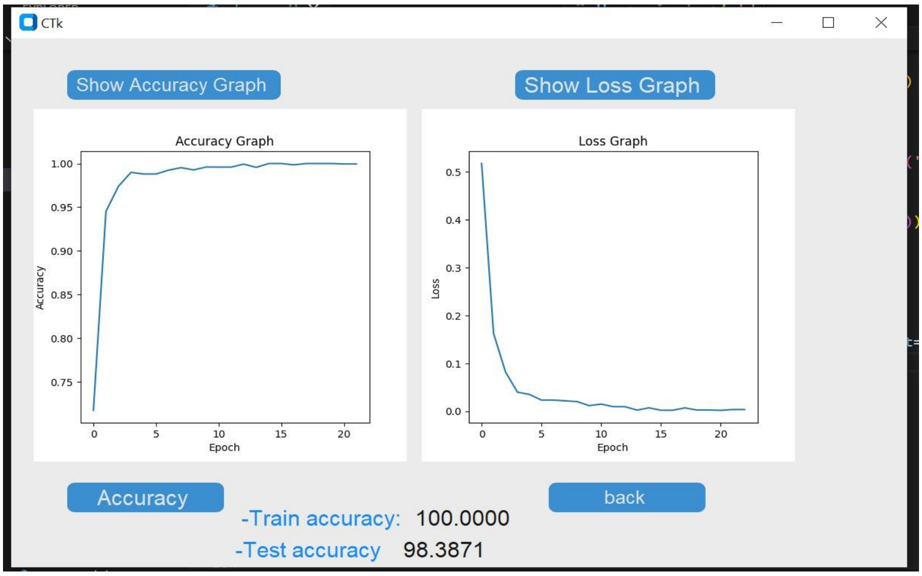


Figure 3.16: Information Page

3.11. Related Work

[64] A.H.N and al., aimed to develop and evaluate the performance of deep-learning models InceptionResNetV2 that automatically classify mesiodens in primary or mixed dentition panoramic radiographs with dataset of size 1100 and achieved an accuracy of 92.40%.

[65] Aljabri and a., apply Deep Learning models InceptionV3 to classify impacted canines from panoramic radiographs with dataset of size 416 and achieved an accuracy of 92.59%.

[66] Vinayahalingam and al., apply Deep Learning models MobileNetV2 with dataset of size 400 to classify the third molars caries on panoramic radiographs and achieved an accuracy of 87.00%.

[67] Kuwada and al., develop deep learning-based models for diagnosing cleft palate (CP) in patients with unilateral or bilateral cleft alveolus (CA) using panoramic radiographs of 491 patients . Two models were created: Model A, which detects the upper incisor area and classifies the presence or absence of CP using DetectNet, and Model B, which directly classifies CP presence using VGG-16. the Model A achieved AUC values of 0.95 for Model A, 0.93 for Model B.

[68] Thanathornwong, B and Suebnukarn, S. A proposes using a deep learning-based object detection method (faster R-CNN) to identify periodontally compromised teeth on digital panoramic radiographs with dataset of size 100, and achieved a presicion of 81.00%.

3.12. Conclusion

In this chapter, we present the environment and tools used to develop machine learning and deep learning models. We discuss the preparation and preprocessing datasets steps involved. Additionally, we focus on the construction and building of the EfficientNetB3 model and compare its performance with EfficientNetB5 and various machine learning models. We then present the obtained results. Finally, we showcase our application interface. And in the next section, we will discuss future perspectives for the development and improvement of our system.

GENERAL CONCLUSION

General Conclusion

In Our work, we focused on the crucial task of dental diagnosis using machine learning and deep learning algorithms, with a specific emphasis on employing an EfficientNetB3 model. Our research aims to advance ongoing efforts to provide fast, effective and advanced diagnosis methods to reduce human error and subjectivity in diagnostic dental procedures.

Through extensive experimentation and analysis, we have achieved promising results in dental diagnosis. Our findings demonstrate the effectiveness of the EfficientNet B3 model in panoramic radiographs imaging, enabling accurate classification between damage and normal teeth, offering the potential to augment the capabilities of dental professionals by providing accurate and timely assessments.

The proposed DL model has achieved a very high accuracy rate of 98.38% and precision of 98.4%. By leveraging the power of deep learning, our EfficientNet B3 model successfully to has proven to be highly effective in classifying teeth in panoramic radiographs.

Despite these promising results, several important limitations must also be highlighted. One of the main challenges we faced was the lack of diverse and comprehensive datasets. Medical datasets often suffer from privacy, the data was unlabeled, and they suffered from biases that may affect the power of the AI model.

Looking to the future, one important perspective is to advance from binary classification to multiclass classification, create and use more representative and meaningful datasets, and apply other models. In addition, we will create a mobile phone application connected to an intraoral camera and an integrated system to provide a more user-friendly experience. Also, taking some pictures with a camera connected to the phone provides promising prospects for the future, where any person can know whether his teeth are infected or not before going to the doctor. Also, we aspire to integrate our program into radiology centers to be used as a rapid diagnostic method.

BIBLIOGRAPHY

Bibliography

[1] K. Shaikh, S. V. Bekal, H. F. A. Marei, W. S. M. Elsayed, D. Surdilovic, and L. A. Jawad, "Artificial Intelligence-Based Dental Diseases Through X-Ray Images Using Entropy CNN-Based and Support Fusion Mating," in Artificial Intelligence in Dentistry, Cham, Switzerland: Springer International Publishing, 2022, pp. 183-195.

[2] Jain, Nityanand, et al. "WHO's global oral health status report 2022: Actions, discussion and implementation." *Oral diseases* (2023).

[3] Featherstone, John DB. "Dental caries: a dynamic disease process." *Australian dental journal* 53.3 (2008): 286-291.

[4]W. Zhang, "Understanding tooth loss: Causes, consequences, and treatment options," J. Clin. Dentistry Oral Health, vol. 7, no. 3, p. 143, 2023.

[5] Rivera, César. "Essentials of oral cancer." *International journal of clinical and experimental pathology* 8.9 (2015): 11884.

[6] Aliev, Bahadur F., and Latafat A. Gardashova. "Selection of an optimal treatment method for acute pulpitis disease." *Procedia computer science* 120 (2017): 539-546.

[7] BOULANOUAR, Souhil Larbi. *Nouvelle méthode hybride pour la segmentation des images médicales IRM*. Diss. Université de M'Sila-Mohamed Boudiaf.

[8] European Society of Radiology (ESR) communications@ myesr. org. "Medical imaging in personalised medicine: a white paper of the research committee of the European Society of Radiology (ESR)." *Insights into imaging* 6 (2015): 141-155.

[9] Farhan, A. L. A. S. "The modern X-ray imaging manners for diagnosis of the dental diseases." *Eurasian Journal of Physics, Chemistry and Mathematics* 7 (2022): 138-48.

[10] Mallya, Sanjay, and Ernest Lam. *White and Pharoah's oral radiology: principles and interpretation*. Elsevier Health Sciences, 2018.

[11] Assiri, Hassan, et al. "Cone beam computed tomography (CBCT) in periodontal diseases: a systematic review based on the efficacy model." *BMC Oral Health* 20 (2020): 115.

[12] Ghoneima, Ahmed, et al. "Three-dimensional imaging and software advances in orthodontics." *Orthod Basic Asp Clin Considerations* 9 (2012): 200-39.

[13] Narula, Harleen, et al. "Conservative non-surgical management of an infected radicular cyst." *Contemporary clinical dentistry* 2.4 (2011): 368-371.

[14] Izzetti, Rossana, et al. "Basic knowledge and new advances in panoramic radiography imaging techniques: a narrative review on what dentists and radiologists should know." *Applied Sciences* 11.17 (20 21): 7858.

[15]Cicciù, Marco, et al. "Early diagnosis on oral and potentially oral malignant lesions: a systematic review on the VELscope® fluorescence method." *Dentistry journal* 7.3 (2019): 93.

[16]Angelone, Francesca, et al. "Diagnostic applications of intraoral scanners: a systematic review." *Journal of Imaging* 9.7 (2023): 134.

[17] Guo, ShuLing, et al. "Feasibility of oral health evaluation by intraoral digital photography: a pilot study." *Journal of International Medical Research* 49.2 (2021): 0300060520982841.

[18] Murdoch, Alexander Ivon King, et al. "Determinants of clinical decision making under uncertainty in dentistry: a scoping review." *Diagnostics* 13.6 (2023): 1076.

[19] Plessas, Anastasios, et al. "Impact of time pressure on dentists' diagnostic performance." *Journal of dentistry* 82 (2019): 38-44.

[20] Khalifa, Mohamed, and Mona Albadawy. "AI in diagnostic imaging: Revolutionising accuracy and efficiency." *Computer Methods and Programs in Biomedicine Update* (2024): 100146.

[21] Thulaseedharan, Athira, and Lal Priya PS. "Deep learning-based object detection algorithm for the detection of dental diseases and differential treatments." *2022 IEEE 19th India Council International Conference (INDICON)*. IEEE, 2022.

[22] Medicalfuturist. 9 Technologies That Will Shape The Future Of Dentistry. https://medicalfuturist.com/the-amazing-future-of-dentistry-and-oral-health/. Accessed: 24 May 2024.

[23] Wu, Yiqun, et al. "Robotics in dental implantology." *Oral and Maxillofacial Surgery Clinics* 31.3 (2019): 513-518.

[24] What Next Global. The internet of teeth: dentistry the smart way. https://whatnextglobal.com/the-internet-of-teeth-dentistry-the-smart-way/. Accessed: 24 May 2024.

[25] P. I. Dorado-Díaz, J. Sampedro-Gómez, V. Vicente-Palacios, and P. L. Sánchez, "Applications of Artificial Intelligence in Cardiology. The Future is Already Here," Revista Española de Cardiología (English Edition), vol. 72, no. 12, pp. 1065–1075, Dec. 2019, doi: 10.1016/j.rec.2019.05.014.

[26] Infodiagram.Ai timeline history machine learning deep learning. https://www.infodiagram.com/slides/ai-timeline-history-machine-learning-deep-learning/.Accessed: 24 May 2024.

[27] Alpaydin, E. (2010). Introduction to machine learning. Cambridge, MA: MIT Press.

[28] Goodfellow, I., Bengio, Y., & Courville, A. (2016). Deep learning. Cambridge: MIT press.

[29] Mohammad Mustafa Taye. Understanding of Machine Learning with Deep Learning: Architectures, Workflow, Applications and Future Directions. Data Science and Artificial Intelligence, Philadelphia University, Amman 19392, Jordan

[30] Bradley C Love. Comparing supervised and unsupervised category learning. Psychonomic bulletin & review, 9(4):829–835, 2002.

[31] Functionize. Discovering the children of ai machine learning deep learning . https://www.functionize.com/blog/discovering-the-children-of-ai-machine-learning-deep-learning. Accessed on April ,27 2024.

[32] Batta Mahesh. Machine learning algorithms-a review. International Journal of Science and Research (IJSR). [Internet], 9:381–386, 2020.

[33] Xiaojin Zhu. Semi-supervised learning literature survey. Technical report, Department of Computer Sciences, University of Wisconsin.

[34] Asma Chebli, Akila Djebbar, and Hayet Farida Marouani. Semi-Supervised Learning for Medical Application: A Survey. 2018 International Conference on Applied Smart Systems (ICASS), pages 1–9, November 2018. Conference Name: 2018 International Conference on Applied Smart Systems (ICASS) ISBN: 9781538668665 Place: Medea, Algeria Publisher: IEEE.

[35] Sutton, R. S., & Barto, A. G. (2018). Reinforcement learning: An introduction. Cambridge, MA: MIT Press.

[36] Understand Q-Learning in Reinforcement Learning with a numerical example and Python implementation, June 2022. Section: Artificial Intelligence.

[37] Jurafsky, Daniel, and James H. Martin. "Chapter 5-Logistic Regression." *Speech and Language Processing*, (2023): 11-17.

[38]Primo ai. Logistic Regression. https://primo.ai/index.php?title=Logistic_Regression_%28LR%29.
Accessed on Mai,23 2024.

[39] Khalid, Sabitha Krishnan, and Rohit M. Thanki. *Artificial intelligence in breast cancer early detection and diagnosis*. Cham: Springer, 2021.

[40] Huang, S., Cai, N., Pacheco, P. P., Narrandes, S., Wang, Y., & Xu, W. (2018). Applications of support vector machine (SVM) learning in cancer genomics. Cancer genomics & proteomics, 15(1), 41-51.

[41] Min-Ling Zhang and Zhi-Hua Zhou. Ml-knn: A lazy learning approach to multi-label learning. Pattern recognition, 40(7):2038–2048, 2007.

[42] Meshram, Pratik S., et al. "A Machine Learning Access for Person Identification using Dental X-Ray Images."

[43] Silver, D., Huang, A., Maddison, C. J., Guez, A., Sifre, L., van den Driessche, G., ... & Hassabis, D. (2016). Mastering the Game of Go with Deep Neural Networks and Tree Search. Nature, 529(7587), 484-489.

[44] S Agatonovic-Kustrin and Rosemary Beresford. Basic concepts of artificial neural network (ann) modeling and its application in pharmaceutical research. Journal of pharmaceutical and biomedical analysis, 22(5):717–727, 2000.

[45] Scielo. Comparative study between multiclass support vector machines, artificial neural networks and self-organized neuro-fuzzy inference system for classification problems. https://www.scielo.cl/scielo.php?script=sci_arttext&pid=S0718-07642020000100273. Accessed on Mai ,23 2024.

[46] Murat H Sazli. A brief review of feed-forward neural networks. Communications Faculty of Sciences University of Ankara Series A2-A3 Physical Sciences and Engineering, 50(01), 2006.

[47] Mekhalfia Mohamed Zakaria, An Innovative Smart System for The Safety of Driver.Mohamed Boudiaf University of M'sila, Algeria. 2023.

[48] Tsai, M.-J.; Tao, Y.-H. Deep Learning Techniques for the Classification of Colorectal Cancer Tissue. Electronics 2021, 10, 166.

[49] Python.org .what is python ?Executive summary.
https://www.python.org/doc/essays/blurb/.Accessed on Mai ,23 2024.

[50] Numpy. Numpy documentation https://numpy.org/doc/stable/. Accessed on Mai 23 2024.

[51] Pandas. Pandas documentation.pandas documentation — pandas 2.2.2 documentation (pydata.org).

[52] Keras Team. Keras: Deep learning library for Python. About Keras 3. Accessed on Mai ,23 2024

[53] TensorFlow. Keras. https://www.tensorflow.org/guide/keras Accessed on Mai,23 2024

[54] OpenCV. About .About - OpenCV, Accessed on Mai,23 2024

[55] Matplotlib. Visualizations with Python. Matplotlib Visualization with Python,
Accessed on Mai, 23 2024

[56] Python. Library Tkinter architecture .tkinter — Python interface to Tcl/Tk — Python 3.12.3 documentation, Accessed on Mai,23 2024

[57] Pedregosa, Fabian, et al. "Scikit-learn: Machine learning in Python." *the Journal of machine Learning research* 12 (2011): 2825-2830.

[58] Kaggle. Panoramic dental xray datasets. https://www.kaggle.com/datasets/daverattan/dental-xrary-tfrecords. Accessed on Mai,23 2024

[59] Kamel Ibrahim, Michael. *Improving Object Detection using Enhanced EfficientNet Architecture*. Diss. 2023.

[60] Salian, Saumya R., and Sudhir D. Sawarkar. "Melanoma skin lesion classification using improved efficientnetb3." *Jordanian Journal of Computers and Information Technology* 8.1 (2022).

[61] Pierre Baldi, Søren Brunak, Yves Chauvin, Claus AF Andersen, and Henrik Nielsen. Assessing the accuracy of prediction algorithms for classification: an overview. Bioinformatics, 16(5):412–424, 20

[62] Katarzyna Janocha and Wojciech Marian Czarnecki. On loss functions for deep neural networks in classification. arXiv preprint arXiv:1702.05659, 2017

[63] Powers, David MW. "Evaluation: from precision, recall and F-measure to ROC, informedness, markedness and correlation." *arXiv preprint arXiv:2010.16061* (2020).

[64] Ahn, Y.; Hwang, J.J.; Jung, Y.-H.; Jeong, T.; Shin, J. Automated Mesiodens Classification System Using Deep Learning on Panoramic Radiographs of Children. Diagnostics 2021, 11, 1477

[65] Aljabri, M.; Aljameel, S.S.; Min-Allah, N.; Alhuthayfi, J.; Alghamdi, L.; Alduhailan, N.; Alfehaid, R.; Alqarawi, R.; Alhareky, M.; Shahin, S.Y.; et al. Canine impaction classification from panoramic dental radiographic images using deep learning models. Inform. Med. Unlocked 2022, 30, 100918.

[66] Vinayahalingam, Shankeeth, et al. "Classification of caries in third molars on panoramic radiographs using deep learning." *Scientific reports* 11.1 (2021): 12609.

[67] Kuwada, Chiaki, et al. "Deep-learning systems for diagnosing cleft palate on panoramic radiographs in patients with cleft alveolus." Oral Radiology 39.2 (2023): 349-354

[68] Thanathornwong, Bhornsawan, and Siriwan Suebnukarn. "Automatic detection of periodontal compromised teeth in digital panoramic radiographs using faster regional convolutional neural networks." *Imaging Science in Dentistry* 50.2 (2020): 169.

Abstract

This project proposes an advanced system for the field of smart dentistry. The system uses advanced AI- techniques based on CNN approach by applying transfer learning and machine learning to diagnose the dental state using panoramic radiographs. Through our experimental work, we have demonstrated the high effectiveness and accuracy of deep learning in dental diagnosis, the achieved accuracy was 98.31% using EffecientnetB3 and 97.38% using EffecientnetB5. The objective of this project is to achieve quick and efficient diagnosis, it can be considered as an important step in the search for more effective and intelligent dental diagnosis solutions thus enhancing the overall quality of dental care.

Keywords: diagnosis, deep learning, CNN, transfer learning, machine learning, panoramic radiography, smart dentistry.

ملخص

يقترح هذا المشروع نظاما متقدما في مجال طب الاسنان الذكي.يستخدم النظام تقنيات الذكاء الاصطناعي المتقدمة القائمة على نموذج الشبكات العصبية التلافيفية من خلال تطبيق التعلم النقلي والتعلم الآلي لتشخيص حالات الاسنان باستخدام الصور الشعاعية البانورامية .من خلال عملنا التجريبي، اثبتنا الفعالية العالية والدقة للتعلم العميق في تشخيص الاسنان حيث بلغت الدقة المحققة 98.31% باستخدام EffecientnetB3 و 97.3 % باستخدام EffecientnetB5. الهدف من هذا المشروع هو تحقيق تشخيص سريع وفعال، ويمكن اعتباره خطوة مهمة في البحث عن حلول تشخيصية أكثر فعالية وذكاءً في مجال طب الأسنان وبالتالي تعزيز الجودة الشاملة لرعاية الأسنان.

الكلمات المفتاحية : التشخيص ، التعلم العميق ، الشبكات العصبية التلافيقية ، نقل التعلم ، التعلم الألي ، التصوير الشعاعي البانورامي ، طب الاسنان الذكي .

Résumé

Ce projet propose un système avancé pour le domaine de la dentisterie intelligente. Le système utilise des techniques d'IA avancées basées sur l'approche CNN en appliquant l'apprentissage par transfert et l'apprentissage automatique pour diagnostiquer l'état dentaires à l'aide de radiographies panoramiques. Grâce à nos travaux expérimentaux, nous avons démontré la grande efficacité et la précision de l'apprentissage profond dans le diagnostic dentaire ,la précision obtenue était de 98,31 % avec EffecientnetB3 et de 97,38 % avec EffecientnetB5.L'objectif de ce projet est d'obtenir un diagnostic rapide et efficace, il peut être considéré comme une étape importante dans la recherche de solutions de diagnostic dentaire plus efficaces et intelligentes, améliorant ainsi la qualité globale des soins dentaires.

Mots clés : diagnostic, apprentissage profond, CNN, apprentissage par transfert, apprentissage automatique, radiographie panoramique, dentisterie intelligente.