

PEOPLE'S DEMOCRATIC REPUBLIC OF ALGERIA  
Ministry of Higher Education and Scientific Research  
Mohamed Boudiaf University of M'SILA  
Faculty of Mathematics and Computer Science  
Computer Science Department



## THESIS

Presented for obtaining the **diploma** of **MASTER**

**In :** Computer Science

**specialization:** Artificial Intelligence

**By:**

AbdeNnour Chergui

Houssam Eddine Boutchicha

## Subject

**The Green Era: Towards a smart ecosystem**

Publicly defended, on 20/06/2023 before the jury consisting of :

M. Tahar Mehenni	Lecturer A	In M'SILA	President
M. Said Gadri	Lecturer A	In M'SILA	Supervisor
M. Hamza Loucif	Lecturer A	In M'SILA	Member

بسم الله الرحمن الرحيم

I dedicate this thesis to my family, whose unwavering support and love have been the driving force behind my academic journey.

# Acknowledgments

I would like to express my deepest gratitude and appreciation to the following individuals and institutions who have contributed to the completion of this thesis.

First and foremost, I am immensely thankful to my thesis advisor, Dr. Said Kadri. Their guidance, expertise, and continuous support have been invaluable throughout this research journey. Their patience, constructive feedback, and unwavering commitment to my academic development have been instrumental in shaping this thesis. I am truly grateful for their mentorship.

I would also like to extend my gratitude to the faculty members of Informatics Department in Msila University, whose knowledge and expertise have greatly influenced my intellectual growth. Their dedication to teaching and research has been a constant source of inspiration.

I would also like to express my appreciation to the participants who willingly took part in this study. Their cooperation and willingness to share their experiences and insights have enriched the findings of this thesis.

Lastly, I would like to thank all those who have directly or indirectly contributed to this thesis. Your contributions, whether through discussions, feedback, or encouragement, have played a significant role in shaping the outcome of this research.

To everyone mentioned above and to those whose names might have inadvertently been omitted, please accept my sincere thanks. Your support and encouragement have been crucial in making this thesis a reality.

## ملخص

يهدف مشروع التخرج هذا إلى معالجة القضايا المتعلقة بأمراض النبات وتعزيز غلة المحاصيل في سياق الثورة الزراعية العالمية. يقترح استخدام تقنيات التعلم العميق والتعلم الآلي لمواجهة هذه التحديات. في البداية، استخدمنا نموذجاً للتعلم العميق لاكتشاف الأمراض النباتية. تركز المرحلة اللاحقة من المشروع على تحسين غلة المحاصيل من خلال الاستفادة من خوارزميات التعلم الآلي، يؤكد هذا المشروع دور دمج التقنيات المتقدمة مثل التعلم العميق والتعلم الآلي في حل العقبات الزراعية.

الكلمات المفتاحية: الزراعة الذكية، التعلم الآلي، التعلم العميق

## Abstract

This graduation project aims to address plant disease issues and promote crop yields in the context of the global agricultural revolution. It is suggested to use deep learning and machine learning techniques to address these challenges. Initially, we used a DL model to automate the detection of plant diseases. The next phase of the project focuses on improving crop yields by leveraging ML algorithms, this project emphasizes the role of integrating advanced technologies such as DL and ML in solving agricultural obstacles.

**Keywords:** Smart Farming, Machine Learning, Deep Learning

## Résumé

Ce projet de fin d'études vise à aborder les maladies des plantes et à promouvoir les rendements des cultures dans le contexte de la révolution agricole mondiale. Il est suggéré d'utiliser des techniques d'apprentissage profond et d'apprentissage automatique pour relever ces défis. Initialement, nous avons utilisé un modèle d'apprentissage profond pour automatiser la détection des maladies des plantes. La prochaine phase du projet se concentre sur l'amélioration des rendements des cultures en tirant parti des algorithmes d'apprentissage automatique, ce projet met l'accent sur le rôle de l'intégration des technologies avancées telles que l'apprentissage profond et l'apprentissage automatique dans la résolution des obstacles agricoles.

**Mots Clés:** agriculture intelligente, Apprentissage Automatique, apprentissage profond

# Contents

Dedication

Acknowledgments

Abstract

List of Figures i

List of Tables ii

**1 GENERAL INTRODUCTION 1**

- 1 Context of the study: . . . . . 2
- 2 Statement of the problem: . . . . . 2
- 3 Objective: . . . . . 3
- 4 Motivation: . . . . . 3
- 5 Report outline: . . . . . 4

**2 Agriculture 6**

- 1 Introduction . . . . . 7
- 2 Importance of agriculture . . . . . 7
- 3 Agriculture for food security . . . . . 7
- 4 Role of agriculture in the global economy . . . . . 8
- 5 Agriculture in Algeria . . . . . 10
  - 5.1 The contribution of agriculture to Algeria’s GDP. . . . . 10
  - 5.2 General land distribution . . . . . 13
- 6 Smart Agriculture . . . . . 13
  - 6.1 Examples of Smart Farming practices . . . . . 15
  - 6.2 Disease Monitoring . . . . . 17
  - 6.3 Soil Fertility analysis . . . . . 17

<b>3</b>	<b>Machine Learning and Deep Learning</b>	<b>20</b>
1	Introduction . . . . .	21
2	Machine learning . . . . .	21
2.1	Definitions . . . . .	21
2.2	The Development of ML Ops . . . . .	22
2.3	Motivation to use Machine Learning . . . . .	23
2.4	Application Fields . . . . .	24
2.5	Machine Learning Requirements . . . . .	24
3	Deep learning . . . . .	25
3.1	Definitions . . . . .	25
3.2	Motivation to use Deep Learning . . . . .	25
3.3	Application Fields . . . . .	26
3.4	Deep Learning Requirements . . . . .	27
3.5	ML VS DL . . . . .	28
4	The Future of AI . . . . .	29
<b>4</b>	<b>Implementation and Experimental Results</b>	<b>31</b>
1	Introduction . . . . .	32
2	The Used Programming Language (Python) . . . . .	32
3	Environment of work (Torch-summary 1.4.5.(2022.3.1)) . . . . .	32
4	Development Tools . . . . .	33
4.1	Anaconda environment: . . . . .	33
4.2	Jupyter: . . . . .	33
4.3	VS Code: . . . . .	33
4.4	Workstation: . . . . .	33
4.5	FastAPI . . . . .	35
5	Used libraries . . . . .	35
5.1	OS: . . . . .	36
5.2	NumPy: . . . . .	36
5.3	pandas (pd): . . . . .	36
5.4	matplotlib.pyplot (plt): . . . . .	36
5.5	Seaborn . . . . .	36
5.6	Keras . . . . .	36
5.7	Joblib . . . . .	37
5.8	sklearn . . . . .	37
6	Data Description . . . . .	38

6.1	Dataset-plant diseases . . . . .	38
6.2	Dataset- Soil Fertility analysis: . . . . .	40
6.3	Used Algorithms . . . . .	42
6.3.1	Used model(ResNet-9) . . . . .	42
6.3.2	Decision Tree classifier . . . . .	42
6.3.3	Naive Bayes . . . . .	43
6.3.4	Support Vector Machines . . . . .	43
6.3.5	Logistic Regression . . . . .	43
6.3.6	Random Forest Classifier . . . . .	43
6.3.7	Recurrent Neural Network . . . . .	44
7	Experimentation . . . . .	44
7.1	plant diseases: . . . . .	44
7.2	Crop Recommendation: . . . . .	46
8	Discussion . . . . .	48
8.1	plant diseases: . . . . .	48
8.2	Crop Recommendation: . . . . .	48
9	Deep Learning and Smart Agriculture Comprehensive Review . . . . .	49
10	Interface . . . . .	50
10.1	Interface of Crop Recommendation . . . . .	51
10.2	Interface of Plant Disease Discovery . . . . .	52
	<b>General Conclusion</b>	<b>53</b>
	<b>Bibliography</b>	<b>55</b>

# List of Figures

2.1	Role of Agriculture in GPD . . . . .	9
2.2	Agriculture Data in Algeria (from 1999 to 2021) . . . . .	12
2.3	Smart farming applications . . . . .	15
2.4	Smart farm concept as part of the “Smart Farm Dispersion Method” in South Korea . . . . .	16
2.5	Some samples issued from our dataset . . . . .	18
3.1	AI Vs ML Vs DS [1] . . . . .	21
3.2	Machine Learning Subfields and Algorithms [2] . . . . .	22
3.3	The evolution of ML Ops . . . . .	23
3.4	Benefits Of ML . . . . .	24
3.5	The architecture of DL . . . . .	25
4.1	Python libraries . . . . .	35
4.2	Some samples from our Used dataset . . . . .	40
4.3	Architecture of Resnet-9 model [3] . . . . .	42
4.4	Crop Recommendation . . . . .	45
4.5	Crop Recommendation . . . . .	46
4.6	Accuracy Comparison on Crop recommendation . . . . .	48
4.7	Home Screen . . . . .	50
4.8	Input and Data Entry and Results of Crop Recommendation . . . . .	51
4.9	Input and Data Entry and Results of Plant Disease Discovery . . . . .	52

# List of Tables

2.1	General land distribution . . . . .	13
4.1	workstation-1- . . . . .	33
4.2	workstation-2- . . . . .	34
4.3	workstation-3- . . . . .	34
4.4	workstation-4- . . . . .	34
4.5	Farmy dataset . . . . .	39
4.6	Data fields . . . . .	40
4.7	Crop Recommendation . . . . .	41
4.8	Obtained Accuracy . . . . .	47
4.9	Obtained Accuracy . . . . .	48

# **Chapter 1**

## **GENERAL INTRODUCTION**

### 1 Context of the study:

Data science involves the use of statistical and computational methods to extract insights from large and complex datasets, while artificial intelligence refers to the development of computer systems that can perform tasks that typically require human intelligence, such as perception, reasoning, learning, and decision-making. In the context of agriculture, data science and artificial intelligence can be used to optimize various aspects of the industry, from crop management and precision agriculture to supply chain management and market forecasting. For example, by analyzing data on weather patterns, soil characteristics, and crop yields, data scientists can develop predictive models that can help farmers make more informed decisions about when to plant and harvest their crops, which can improve yields and reduce waste. Similarly, artificial intelligence can be used to develop autonomous agricultural machinery that can perform tasks such as planting, watering, and harvesting crops.

This technology has the potential to significantly reduce labor costs and increase efficiency, which can help farmers maximize profits and improve the sustainability of their operations. In this graduate thesis, we will explore the application of data science and artificial intelligence in the field of agriculture, with a focus on crop management and precision agriculture. Specifically, we will develop predictive models that can be used to forecast crop yields and optimize fertilizer and pesticide application, using data on weather patterns, soil characteristics, and crop health. Overall, this thesis aims to demonstrate the potential of data science and artificial intelligence to revolutionize the agriculture industry, and to provide insights that can help farmers and policymakers make more informed decisions about how to optimize their operations and improve the sustainability of the industry.

### 2 Statement of the problem:

Despite significant advancements in agriculture, small-scale farmers continue to face challenges due to limited understanding of plant diseases and crop recommendations. Our study addresses several key issues, with the primary challenge being the automation of computer vision-based plant disease diagnosis. Additionally, a secondary difficulty lies in determining appropriate crops based on the specific soil characteristics of a given piece of land. Through our research, we aim to empower farmers by harnessing internet services and technological advancements to bridge knowledge gaps, tackle plant diseases, and provide tailored crop recommendations for their unique circumstances.

- What is the specific disease being referred to?(Diagnosis, image classification)

## **Chapter 1. GENERAL INTRODUCTION**

---

- Why does the classifier determine that a particular disease is present?(Explainability, Disease symptoms)
- How can the classifier be deployed for use by farmers?
- What types of crops can be grown based on the characteristics of the soil in a particular land?
- Which algorithm is employed to determine the compatibility between soil characteristics and various plant types?

### **3 Objective:**

The objective of this project is to create an intelligent agricultural system that benefits both investors and small-scale farmers. The system will primarily concentrate on detecting crop diseases and providing crop recommendations based on soil characteristics. By utilizing this system, users will have the opportunity to enhance their crop production while minimizing the risk of losses caused by diseases.

### **4 Motivation:**

Impact on smart agriculture in Algeria has been motivated by a number of factors, particularly as part of the government's goal to promote investments, improve the nation's food security, and increase the availability of widely consumed food items. The following are some important causes of this motivation:

- **Technological Advancements:** The advancements in digital technologies, Internet of Things (IoT), and data analytics have opened up new possibilities in agriculture. By integrating these technologies into farming practices, Algerian farmers can monitor crop conditions, soil health, and weather patterns in real-time. This data-driven approach enables them to make informed decisions about irrigation, fertilizer application, and pest management, resulting in higher yields and more efficient resource utilization.
- **Economic Diversification:** Algeria has traditionally relied on oil and gas exports as a major source of revenue. However, the country aims to diversify its economy and reduce its dependence on hydrocarbon resources. Investing in smart agriculture presents an opportunity to develop a sustainable agricultural sector, create employment opportunities, and stimulate economic growth. By attracting investments in smart agriculture, Algeria

## **Chapter 1. GENERAL INTRODUCTION**

---

can promote entrepreneurship, innovation, and technological development in the agricultural sector.

- **Population Growth:** Algeria has a growing population, and feeding a larger number of people requires a significant boost in agricultural production. Smart agriculture can contribute to meeting this challenge by employing innovative technologies to optimize land use, conserve water resources, and improve crop productivity. By adopting smart agriculture practices, Algeria can strive to meet the increasing food demand of its population.
- **Regional and International Cooperation:** Smart agriculture initiatives can enhance collaboration between Algeria and other countries, organizations, and research institutions working in the field of agricultural innovation. By engaging in knowledge sharing, capacity building, and technology transfer, Algeria can leverage international expertise and experiences to accelerate its agricultural development. This cooperation can lead to increased investments, improved research and development, and access to markets for Algerian agricultural products.

investing in smart agriculture aligns with Algeria's goals of achieving food security, increasing agricultural production, diversifying its economy, promoting sustainability, and fostering regional and international cooperation. By embracing innovative technologies and practices, Algeria can unlock the potential of its agricultural sector, improve productivity, and contribute to the well-being of its population.

## **5 Report outline:**

This document is divided into four chapters plus the conclusion as follows:

- The First chapter presents a general introduction: It offers an overview of the impact of artificial intelligence (AI) in agriculture, highlighting its significance. The chapter also discusses the problem statement, specifically focusing on the Motivation for smart agriculture in Algeria. Finally, the chapter concludes by outlining the structure and content of the document.
- The second chapter focuses on agriculture's impact on the global economy, emphasizing its importance for food security. It examines Algeria's agricultural sector and discusses the concept of smart agriculture. The chapter also explores countries that have embraced smart agriculture and discusses the significance of plant diseases and soil fertility on agricultural productivity.

## **Chapter 1. GENERAL INTRODUCTION**

---

- The Third chapter delves into the topic of machine learning and deep learning. It provides an overview of these concepts, discussing their fundamental principles and algorithms.
- Chapter 4 focuses on the implementation and experimental results of the project. It outlines the practical aspects of implementing the proposed solution or model
- Finally,we offer a conclusion of our work, encompassing the key aspects of our project, including its advantages, limitations, and future possibilities.

# **Chapter 2**

## **Agriculture**

### 1 Introduction

The “Agriculture” word is derived from two Latin words, agricultūra, from ager, "field", and cultūra, "cultivation" or "growing". Agriculture has been one of the most important human activities throughout history, providing food and other essential resources for human societies. Agriculture has played a significant role in shaping public life, from the development of early civilizations to the industrialization of modern societies. However, the impact of agriculture on public life has been a topic of debate and concern for many years, with issues such as food security, environmental degradation, and economic inequality at the forefront of discussions. Agriculture is an essential sector of the global economy. It accounts for 4% of global GDP and supports job creation and economic development [4]. Although it accounts for a comparatively small share of the global economy, agriculture impacts global trade and is crucial to economic growth [5]. Despite not receiving as much attention as other sectors of the economy, agriculture is important and has significant impacts on the economy [6]. In addition, agriculture can help reduce poverty, raise incomes, and improve food security for the world’s poor, who live in rural areas and work in agriculture [4].

### 2 Importance of agriculture

There are several reasons why agriculture holds significant importance. Firstly, it sustains livelihoods by providing food, habitat, and employment opportunities. Additionally, it serves as a crucial source of raw materials for the production of various food items and other products. Furthermore, it facilitates trade and helps in building robust economies. Agriculture can also play a crucial role in eradicating extreme poverty, promoting shared prosperity, and catering to the needs of an ever-growing population. It involves the art and science of cultivating the soil, growing crops, and raising livestock. Developing countries consider agriculture as the backbone of their economic systems due to its pivotal role in their economies.

### 3 Agriculture for food security

Agriculture plays a crucial role in ensuring food security, which refers to the availability, accessibility, and affordability of sufficient, safe, and nutritious food for all people at all times. Agriculture is essential for food security, particularly in developing countries [7]. Agriculture provides the necessary food and nutrition for people around the world, and it also supports livelihoods, particularly in rural areas. However, agriculture can face many challenges, such as climate change, water scarcity, soil degradation, and pests and diseases, which can impact food

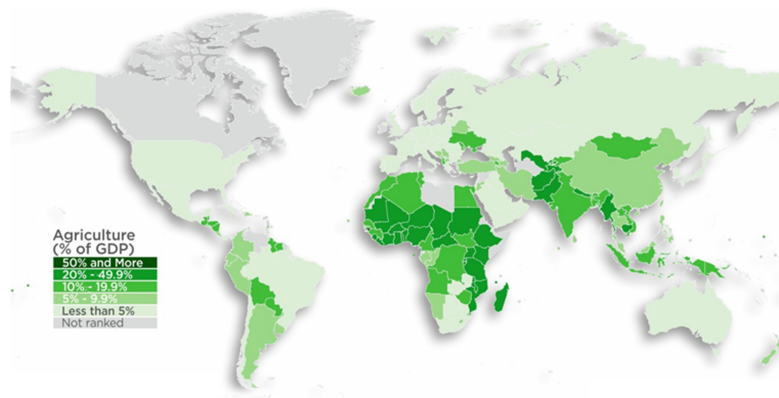
production and supply.

To achieve food security through agriculture, it is important to increase agricultural productivity and efficiency, promote sustainable agricultural practices, and improve access to markets and technologies for small-scale farmers. This includes investing in agricultural research and development, improving infrastructure and transportation networks, and providing financial and technical support to farmers.

Furthermore, it is important to promote diversification of crops and livestock, as well as the conservation of crop genetic diversity, which can help to enhance resilience to climate change and other stresses. Finally, policies that support agriculture and rural development, such as investments in education and health, can also contribute to achieving food security.

## 4 Role of agriculture in the global economy

The agricultural sector plays a crucial role in the economic development of a country, as it is strategically positioned to contribute significantly to the country's growth. While advanced countries have already experienced substantial economic prosperity due to the development of their agricultural sectors, the role of agriculture in the economic growth of less developed countries is of utmost importance. This is because agriculture serves as a primary source of livelihood for a considerable percentage of the population in developing nations, and its growth can lead to the creation of employment opportunities, the development of rural areas, and increased food security. Therefore, investing in the agricultural sector can be an effective way to promote economic development and reduce poverty in less developed countries. A fundamental commonality shared by all individuals on earth is the essential requirement for sustenance, making agricultural production a crucial driver of the global economy. The productivity of agriculture is influenced by various factors, including the climatic conditions, availability of cultivable land, access to technology, and labor force, which have different effects across different regions of the world. In our latest set of visual representations, we delve deeper into the variability of agriculture's contribution to a country's GDP and the number of individuals employed in agriculture worldwide. [8]



**Figure 2.1:** Role of Agriculture in GDP

By utilizing supplementary data from The World Bank’s World Development Indicators, it is possible to ascertain the disparities in agricultural output and employment across different nations. [9]

- The portion of the global Gross Domestic Product (GDP) attributed to agriculture has been decreasing over time, standing at 3% in 2018, which is a decline from 4% in 2010.
  - It is worth noting that despite its relatively small contribution to the world’s overall output, the agricultural sector provides employment for a significant portion of the global workforce, amounting to 30%
  - It appears that developing countries have larger agricultural sectors compared to developed countries, and this sector constitutes a higher percentage of their domestic GDP.
  - Southeast Asian and African nations exhibit a significantly greater dependence on agriculture as a proportion of their total Gross Domestic Product (GDP) (Fig.2.1).
1. Americas: There is a notable gap in agricultural production between developed and developing nations. The United States, for instance, has a lower number of individuals employed in agriculture, yet it generates a greater amount of agricultural output compared to countries in Central and South America, where a higher percentage of the population is involved in agricultural activities.
  2. Asia Oceania: South and Southeast Asian countries exhibit the highest levels of both agricultural production and employment, whereas Middle Eastern countries such as Oman and Yemen have the lowest agricultural output. More than half of the population in

Nepal and Myanmar are employed in the agricultural sector, and countries like Papua New Guinea and Timor-Leste in Oceania have over half of their workforce engaged in agriculture.

3. Europe: While most European countries have less than 10% of their workforce employed in agriculture, countries such as Albania, Azerbaijan, and Georgia have more than 30% of their population earning a livelihood from this sector. Turkey and most Western European countries have the highest levels of agricultural output.
4. Africa: Agriculture is a crucial source of income for many countries in Africa, with more than a third of the GDP in eight countries being derived from agricultural output. Additionally, in countries such as Niger, Chad, and Uganda, over 70% of the population works in the agricultural sector.

## 5 Agriculture in Algeria

Agriculture has historically played an important role in the economy of Algeria, but its contribution to the country's GDP has declined over the years as other sectors such as industry and services have grown.

Algeria has a diverse range of agricultural products, including cereals, vegetables, fruits, and livestock. The country is self-sufficient in certain crops such as wheat, barley, and dates, but it relies heavily on imports for other food items such as sugar and vegetable oil.

Agricultural production in Algeria faces several challenges, including limited access to irrigation water, a shortage of arable land, and soil degradation. In recent years, the government has implemented policies to support the modernization of agriculture, including investments in irrigation infrastructure and the promotion of new technologies.

Despite these challenges, agriculture remains an important sector for rural development and job creation in Algeria, particularly in the southern regions of the country where nomadic and pastoralist communities rely on livestock and crop cultivation for their livelihoods.

### 5.1 The contribution of agriculture to Algeria's GDP.

ALGERIA it has a diverse economy with various sectors such as agriculture, industry, and services. While agriculture remains an important sector in Algeria, the country's economy has shifted towards other industries such as oil and gas. As a result, the GDP share of agriculture in Algeria has decreased over the years, although it still plays a significant role in the country's economy. The President of the Republic, Mr. Abdelmadjid Tebboune, defines the peasant

## Chapter 2. Agriculture

---

strategy under the current international circumstances during the national agriculture meetings [10]:

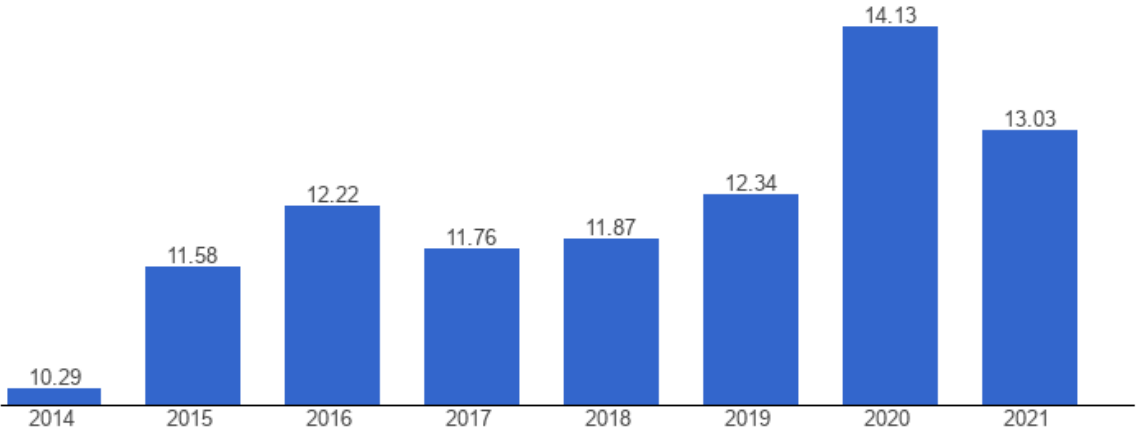
- Agriculture accounts for 14.7 per cent of rough domestic output, and is second only to burns of 24 per cent.
- Grain will be of paramount importance in our agricultural production strategy.
- You're going to consume 9 million tons of wheat a year, and we got to produce half of that amount, but what's holding us back is over half, the lack of rigour in the sector, and I don't say indifference.
- Foreigners ask me surprisingly why Algeria imports cereals despite its water potential and vast agricultural areas.
- We will approach comfort food security if we reach a national production rate of 35 quintals per hectare.
- Agricultural production increased by 1,000 billion dinars, or approximately 10 billion dollars.
- Agriculture in the South currently requires other measures, including twice-yearly production.
- Our southern States alone, capable of achieving cereal self-sufficiency.
- We will stimulate those who achieve crop production, twice a year, to benefit from state support and catalysts together.
- We are not far from achieving self-sufficiency, provided that production is satisfied and not under the pressure of official demands.
- Pride in the olive oil produced by Wade Will and the international reputation he has become. - Ready to finance farming-related industries projects up to 90%.
- I wish our young people to move more and more towards farming and transforming peasant materials through emerging institutions.
- The Green Dam is a fortune and we have to intensify it with fruitful trees such as pistachios and almonds.
- Forests are open to Algerian investors in beekeeping and even for grazing.

## Chapter 2. Agriculture

---

- The Ministry of Agriculture must go towards a peasant management model in which the Ministry of Agriculture has mere authority to control and direct and the decision-maker is the peasant.
- We must know once and for all that wheat is a strategic crop and wealth that promotes the independence of the State's decisions, which is directed at citizens and not food for the public.
- I wish our young people to move more and more towards farming and transforming peasant materials through emerging institutions.

we provide data of Algerian agriculture. from 1999 to 2021. The average value for Algeria during that period was 9.95 % with a minimum of 6.59 % in 2008 and a maximum of 14.13% in 2020. The latest value from 2021 is 13.03 %. For comparison, the world average in 2021 based on 166 countries is 10.35 %. [11].



**Figure 2.2:** Agriculture Data in Algeria (from 1999 to 2021)

### 5.2 General land distribution

According to the nomenclature used by the FAO for the world census of agriculture, the distribution of land in Algeria is presented in the table below. The total area of Algeria is approximately 238 million hectares and is divided as follows [12]:

**Table 2.1:** General land distribution

Category	Area (million ha)	Percentage of Total
Total Area of Algeria	238	–
1. Total Agricultural Land (T.A.L)	44.00	18.5%
-Pastures and Pastures	32.75	74.5%
-Unproductive Land on Agricultural Holdings	2.65	6.0%
-Useful Agricultural Land (U.A.L)	8.56	19.5%
-Herbaceous Crops	4.68	54.67%
-Resting Land	2.85	33.26%
-Fruit Plantations	0.91	10.63%
-Vignobles	0.07	0.80%
-Natural Meadows	0.05	0.63%
2. Alfalfa Land	2.47	1.0%
3. Forested Land	4.10	1.7%
4. Unproductive Land not Used for Agriculture	187.60	78.8%

## 6 Smart Agriculture

Smart agriculture, also known as precision agriculture or digital agriculture, is a farming method that integrates technology to enhance the efficiency and profitability of agricultural practices. This type of agriculture relies on the use of sensors, drones, machine learning, and other technological advancements to make farming more precise, sustainable, and resource-efficient.

One of the key benefits of smart agriculture is its ability to improve crop yields while reducing the use of inputs such as water, pesticides, and fertilizers. For example, sensors that measure soil moisture and nutrient levels can help farmers apply water and nutrients only where and when they are needed. This not only reduces waste but also lowers operating costs and increases profitability.

Smart agriculture also enables farmers to monitor crops in real-time and respond quickly to changes in weather conditions, pests, and diseases. Drones equipped with cameras or thermal imaging sensors can help identify problem areas in the field, allowing farmers to take corrective actions before the issues become more severe. This can help prevent yield losses and reduce the

## Chapter 2. Agriculture

---

need for costly and potentially harmful pesticides and other chemicals .

Another advantage of smart agriculture is its potential to enable more efficient use of labor. For example, autonomous vehicles or robots can be used for tasks such as planting, harvesting, and weeding, freeing up human labor for other tasks.

In addition to these benefits, smart agriculture also has the potential to reduce the environmental impact of farming. By optimizing inputs and minimizing waste, this method of farming can help reduce greenhouse gas emissions, soil erosion, and water pollution. Overall, smart agriculture represents a major shift in the way that farmers approach their work. By leveraging technology to optimize inputs and improve efficiency, this approach has the potential to not only increase crop yields and profitability but also improve sustainability and reduce the environmental impact of farming.

### **Additional details on smart agriculture** [13]

- Precision agriculture is a crucial aspect of modern agriculture, utilizing various technologies such as sensors, GPS, and other tools to gather information about crop growth, soil moisture levels, and weather conditions. This data is then analyzed and used to create precise maps of the farm, which enable farmers to make more informed decisions regarding resource management and waste reduction. Through precision agriculture, farmers are able to apply fertilizers and pesticides in targeted areas, thereby reducing costs and minimizing negative environmental effects.
- In smart agriculture, the Internet of Things (IoT) and sensors play vital roles. Through the use of IoT devices, data can be collected from various sensors situated across the farm, such as weather stations, soil moisture sensors, and crop health sensors. This data is then transmitted to a central platform where it is analyzed and used to make informed decisions regarding farming operations.
- The usage of drones in agriculture is becoming more prevalent as they are capable of collecting data on crops and farm conditions. Equipped with cameras and sensors, drones can capture high-resolution images and gather data on plant health, soil conditions, and crop yields. The data collected by drones is then analyzed to create comprehensive maps of the farm, which can be used to identify areas that require particular attention.
- Smart agriculture heavily relies on data analytics to make informed decisions. Through the analysis of data obtained from various sources such as sensors and drones, farmers can make informed decisions about when to plant, irrigate, fertilize, and harvest their crops. Additionally, data analytics can identify patterns and trends, enabling farmers to adjust

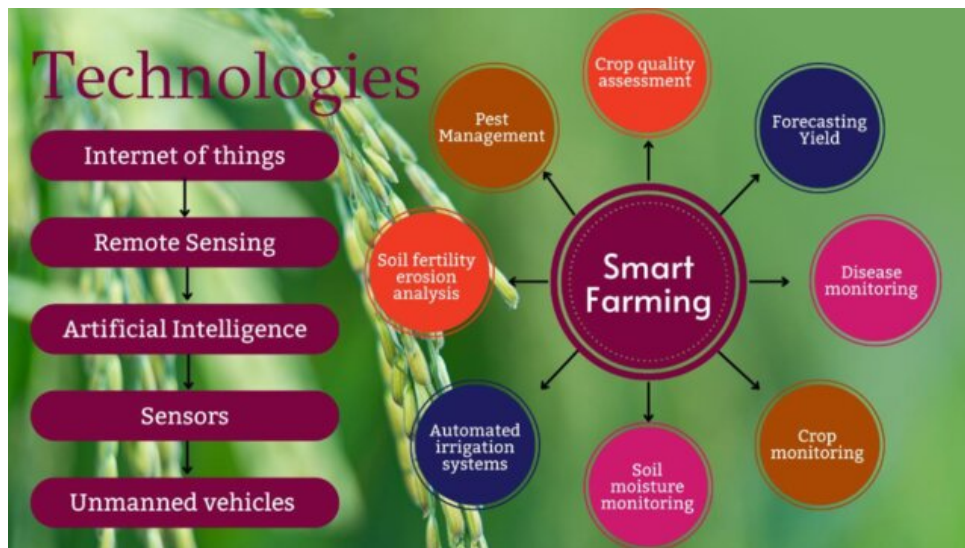
## Chapter 2. Agriculture

---

their practices to optimize crop yields and reduce costs. In this manner, data analytics serves as a crucial component in the success of smart agriculture.

- **Benefits of smart agriculture:** Smart agriculture has the potential to revolutionize the way we produce food. By optimizing resource use and reducing waste, smart agriculture can help to make agriculture more sustainable and profitable. Smart agriculture can also help to increase food production, which is essential to feed a growing global population. Additionally, smart agriculture can help to reduce environmental impact by minimizing the use of fertilizers and pesticides and reducing water consumption.

The figure depicts the usage of smart agriculture applications in the field of agriculture [14].



**Figure 2.3:** Smart farming applications

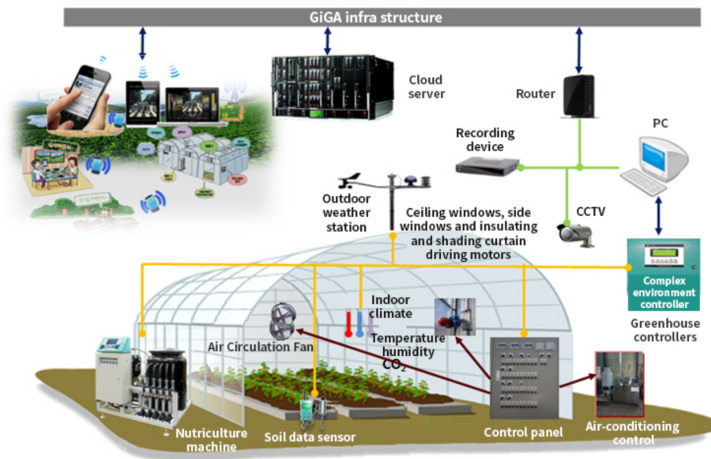
### 6.1 Examples of Smart Farming practices

Below are several examples of countries that have effectively implemented smart farming practices, as showcased by their respective models.

- **South Korea:** South Korea stands out as a prime example of a country that has taken decisive action by implementing a comprehensive national policy aimed at establishing smart farming communities. This initiative encompasses the entire agri-food supply chain and leverages advanced technologies like sensors, drones, and big data analytics to maximize crop yields while minimizing waste. Moreover, the South Korean government has introduced financial incentives to encourage farmers to embrace these cutting-edge technologies, leading to notable enhancements in productivity and profitability [15]. In Fig, the concept of a smart farm is depicted as an integral component of the 'Smart Farm

## Chapter 2. Agriculture

Dispersion Method' implemented in South Korea by the Ministry of Agriculture, Food and Rural Affairs (MAFRA) in 2021 [15].



**Figure 2.4:** Smart farm concept as part of the “Smart Farm Dispersion Method” in South Korea

- Ghana: Ghana stands out as a prime example of a nation that has effectively implemented smart farming practices. Through its climate-smart agriculture project, Ghana has achieved remarkable progress in enhancing the lives of over 7 million farmers and 4 million households. The initiative encompasses a range of innovative technologies, including the cultivation of drought-resistant crops, adoption of conservation agriculture, and implementation of agroforestry methods. These advancements have led to heightened crop yields, enhanced soil health, and significant reduction in greenhouse gas emissions. Moreover, the project has bolstered the ability of farmers to withstand the impacts of climate change, making Ghana a noteworthy success story in the realm of smart farming [16].
- Netherlands: The Netherlands has emerged as a frontrunner in the implementation of smart farming practices, specifically in the realm of precision agriculture. The country has been at the forefront of utilizing cutting-edge technologies like GPS, drones, and sensors to maximize crop yields while minimizing waste. Notably, the Dutch government has played a pivotal role by offering financial incentives to farmers, encouraging them to embrace these advanced technologies. As a result, the agricultural sector has witnessed significant improvements in productivity and profitability. The Netherlands' leadership in adopting smart farming techniques, particularly in the field of precision agriculture, serves as a noteworthy example for other nations to follow [17].

Both South Korea, Ghana and the Netherlands have successfully implemented smart farming practices, leading to noteworthy advancements in agricultural productivity, sustainability, and

profitability. These initiatives have been carefully designed, considering various factors such as climate conditions, soil types, and available local resources. By tailoring the smart farming approaches to suit the specific needs of each country, both nations have been able to achieve significant positive outcomes in their agricultural sectors. The emphasis on customization and adaptation has played a crucial role in optimizing the benefits of smart farming practices in these countries.

### 6.2 Disease Monitoring

The rise in plant disease outbreaks is putting the food security of vulnerable populations around the world at risk, while a global human pandemic is threatening the health of millions. In order to lift people out of poverty and improve health outcomes, it is crucial to ensure a stable and nutritious food supply. Unfortunately, both endemic and emerging plant diseases are spreading due to factors such as climate change, transmission through global food trade networks, pathogen spillover, and the evolution of new pathogen lineages. To address these challenges, it is essential to develop a new set of tools that include disease surveillance and improved detection technologies like pathogen sensors, predictive modeling, and data analytics, which will help prevent future outbreaks.

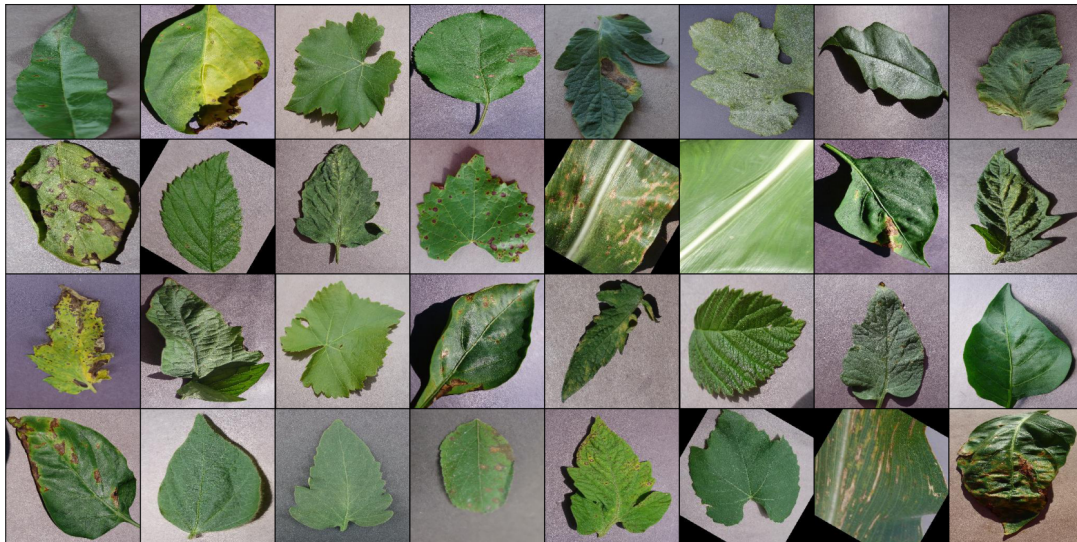
The United States Department of Agriculture's Agricultural Research Service (ARS) is involved in researching plant diseases, covering various areas such as etiology, identification, genomics, and management of plant health, [18] During the fiscal year of 2020, researchers at ARS made significant progress in forecasting the dissemination of two highly destructive citrus diseases that were caused by hurricanes [19].

Deep learning has emerged as a promising method for detecting plant diseases and pests, offering a potential alternative to traditional algorithms that rely on manual image recognition features. Unlike the challenging and subjective nature of manual approaches, deep learning techniques provide a more reliable and less luck-dependent solution [20].

### 6.3 Soil Fertility analysis

To recommend the best crops to grow on a specific farm based on various parameters, we need to analyze the conditions of the farm and compare them with the ideal growing conditions of different crops. Here are recommendations based on the given parameters:

1. Here are recommendations based on the given parameters: These ratios are essential for plant growth and development. Nitrogen is necessary for leaf development, while phosphorous is essential for root development and potassium for the overall health and growth of the plant. Based on these ratios, would recommend crops such as wheat, corn,



**Figure 2.5:** Some samples issued from our dataset

and rice that require higher levels of nitrogen and phosphorous. For crops that require higher levels of potassium, such as tomatoes and potatoes, would recommend adjusting the soil's potassium levels accordingly [21].

2. **Temperature:** Temperature plays a vital role in crop growth and development. Different crops have different temperature requirements for optimal growth. For example, crops like tomatoes and peppers require warmer temperatures, while crops like lettuce and spinach prefer cooler temperatures. Based on the local climate, I would recommend crops that are suitable for the temperature range of the farm [18].
3. **Humidity:** Humidity affects plant growth by influencing transpiration rates and nutrient uptake. High humidity levels can lead to fungal diseases in plants. Crops like rice, corn, and wheat can tolerate higher humidity levels, while crops like tomatoes and strawberries prefer lower humidity levels. Therefore, I would recommend crops that are suitable for the local humidity levels [19].
4. **The pH value of soil** affects the availability of nutrients to plants. Most crops grow best in soil with a pH range of 6-7.5. If the soil pH is too acidic or alkaline, some crops may not grow well. For example, blueberries require acidic soil, while asparagus prefers alkaline soil. Therefore, I would recommend crops that are best suited for the soil pH of the farm [20].
5. **Rainfall:** Rainfall is an essential factor in determining crop suitability. Different crops have different water requirements. For example, crops like rice require high levels of water, while crops like tomatoes require moderate levels of water. Based on the amount

## Chapter 2. Agriculture

---

of rainfall in the region, would recommend crops that can tolerate the local rainfall levels [22].

By taking into account various parameters such as soil nutrient ratios (N, P, and K), temperature, humidity, soil pH, and rainfall, it is possible to determine the most suitable crops to grow on a specific farm. Considering these factors and the local growing conditions, a recommendation can be made regarding the crops that would thrive best on the farm, ultimately ensuring optimal growth and maximizing yields.

## **Chapter 3**

# **Machine Learning and Deep Learning**

# 1 Introduction

Artificial Intelligence (AI) is a field dedicated to creating machines that possess the ability to think and behave in a manner similar to humans.

Machine learning (ML) and deep learning (DL) are both subfields of artificial intelligence (AI) that focus on creating algorithms and models capable of learning from data. While they share some similarities, they also have distinct differences and applications Here's a concise overview of ML and DL [23].

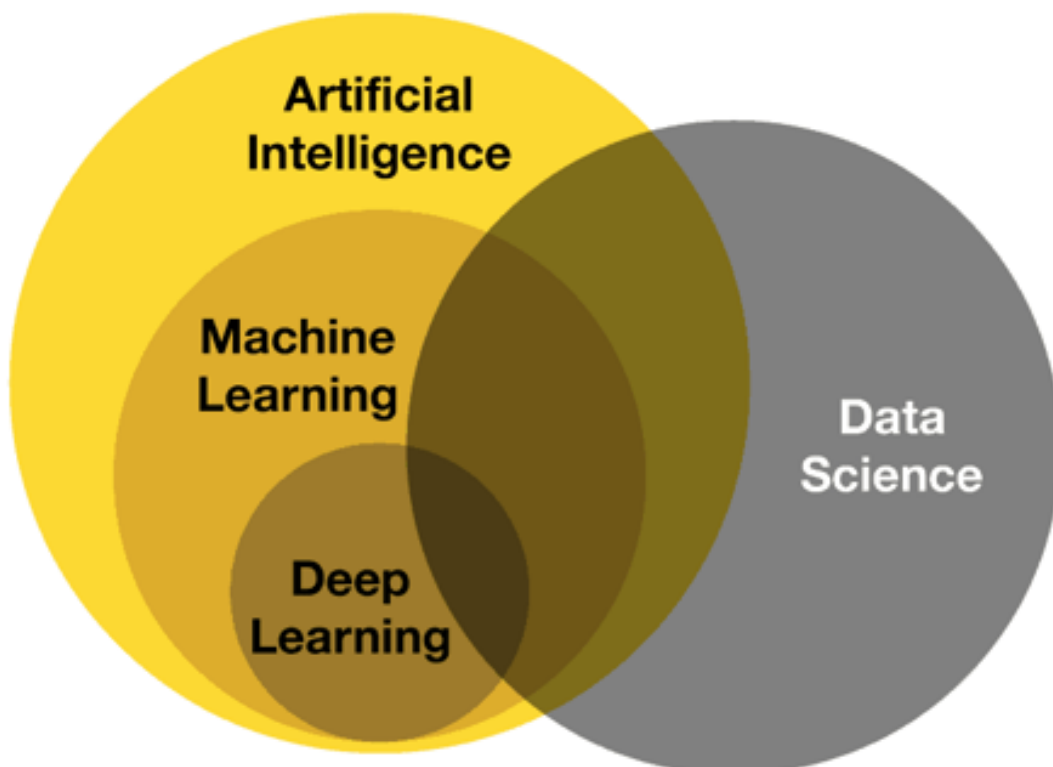


Figure 3.1: AI Vs ML Vs DS [1]

## 2 Machine learning

### 2.1 Definitions

Machine learning is indeed a scientific field that falls under the broader umbrella of artificial intelligence (AI). It revolves around the concept of using algorithms to automatically discover patterns in data and learn from them to perform specific tasks or make predictions. This ability

## Chapter 3. Machine Learning and Deep Learning

to learn from data sets it apart from traditional programming, where explicit instructions are provided to solve a problem.

In machine learning, data serves as the fuel for training algorithms. This data can take various forms, such as numerical values, text, images, audio, or any other type of information that can be stored digitally. The algorithms process and analyze this data to uncover underlying patterns and relationships [24].

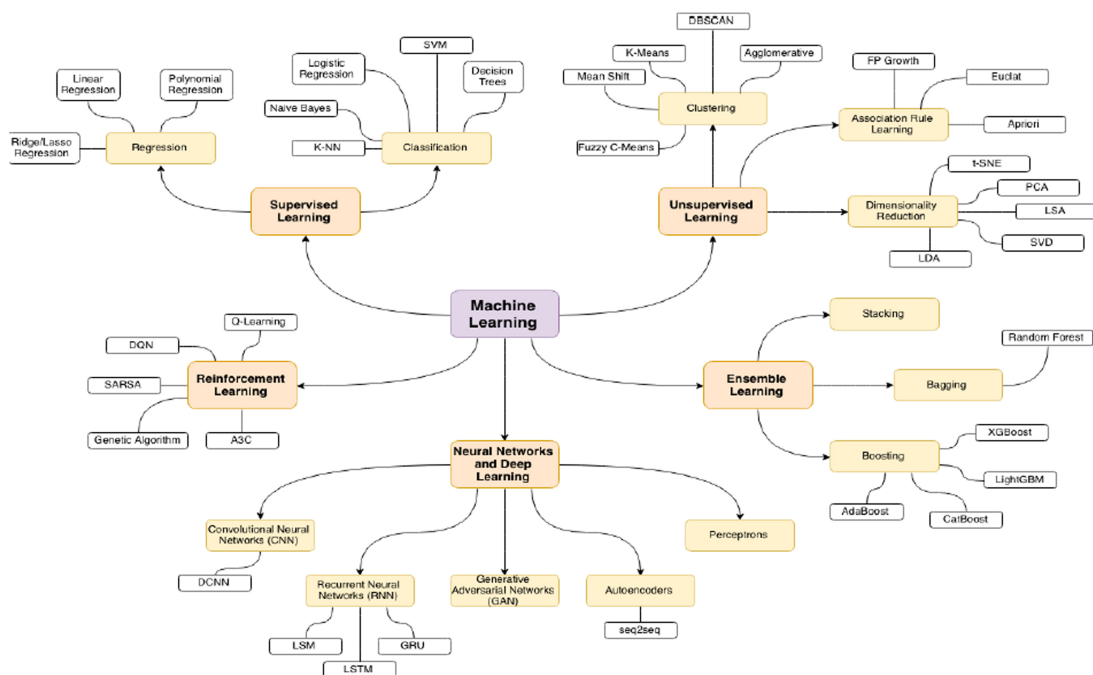


Figure 3.2: Machine Learning Subfields and Algorithms [2]

### 2.2 The Development of ML Ops

During the early 2000s, companies relied on licensed software like SAS, SPSS, and FICO to implement machine learning solutions. As open-source software and data availability increased, practitioners began using Python or R libraries for training ML models. However, integrating these models into production remained challenging. The emergence of containerization technology addressed scalability concerns through the use of Docker containers and Kubernetes for model deployment. Recently, we have witnessed the progression of these solutions into comprehensive ML deployment platforms that encompass the entire process of model experimentation, training, deployment, and monitoring. The diagram below illustrates the evolution of MLOps [25].

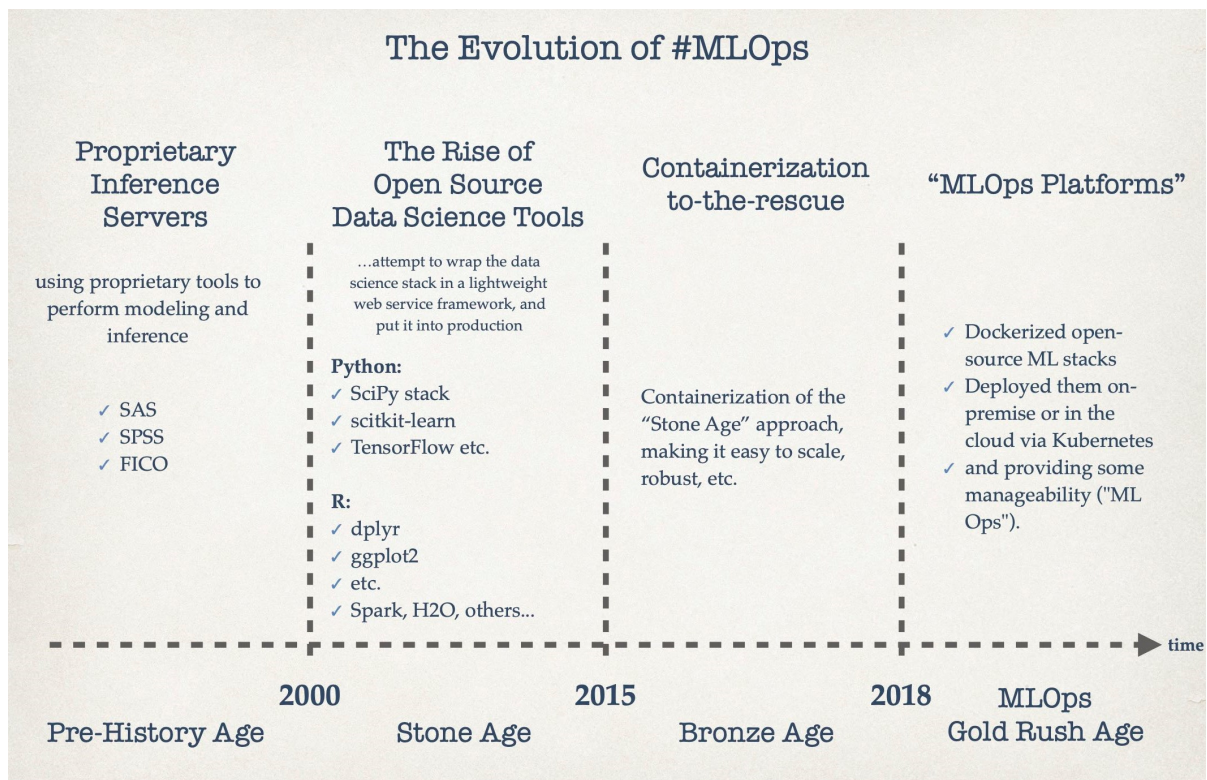
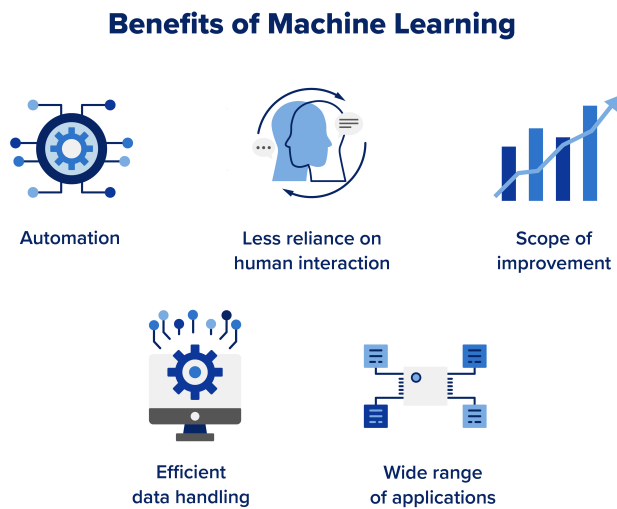


Figure 3.3: The evolution of ML Ops

### 2.3 Motivation to use Machine Learning

There are several motivations for using machine learning:

- Addressing complex problems: Machine learning can tackle intricate issues that may pose challenges when using conventional methods [25].
- Career advancement and higher salaries: Acquiring knowledge in machine learning can open doors to enhanced career prospects and increased earning potential [26].
- Pattern observation and prediction: Machine learning enables the identification of patterns and the ability to make predictions based on gathered data [27].
- Emotionally engaging individuals and enhancing marketing: Through the utilization of Motivation AI, machine learning can emotionally engage individuals and improve marketing efforts by understanding and responding to their motivations [28].
- Task automation and efficiency improvement: Machine learning facilitates automating tasks, leading to enhanced efficiency in various domains [29].



**Figure 3.4:** Benefits Of ML

### 2.4 Application Fields

Machine learning underlies a vast array of tools that find frequent application in our daily lives. Its presence is evident in our social media platforms, interactions with customer service, and data analytics. Moreover, the applications of machine learning are steadily expanding, encompassing a wide range of use cases. Here are a few examples of the most prevalent applications of machine learning.

- Image recognition
- Text generation and analysis
- Speech recognition
- Data analytics
- Algorithmic recommendations

### 2.5 Machine Learning Requirements

The essence of machine learning rests upon two fundamental components.

- Firstly, we have the data, which serves as the set of examples from which the algorithm learns.

- Secondly, we have the learning algorithm itself, which is the procedure executed on the data to generate a model. The process of applying a learning algorithm to a dataset is commonly referred to as training [2].

### 3 Deep learning

#### 3.1 Definitions

Deep Learning (DL) is a sub-domain of Machine Learning (ML) wherein a model is trained to perform classification tasks directly on images or texts. DL exclusively utilizes artificial neural networks (ANNs) to construct the appropriate model. The term "Deep" in Deep Learning refers to the utilization of multiple layers of neurons in the network. As the number of layers increases, the network becomes deeper. In contrast, traditional neural networks typically consist of only two or three layers, while deep networks can encompass hundreds or even thousands of layers. A Deep Learning architecture comprises input layers, hidden layers, and an output layer. Each layer within the architecture is interconnected, with the output of each layer serving as input for the subsequent layer [30].

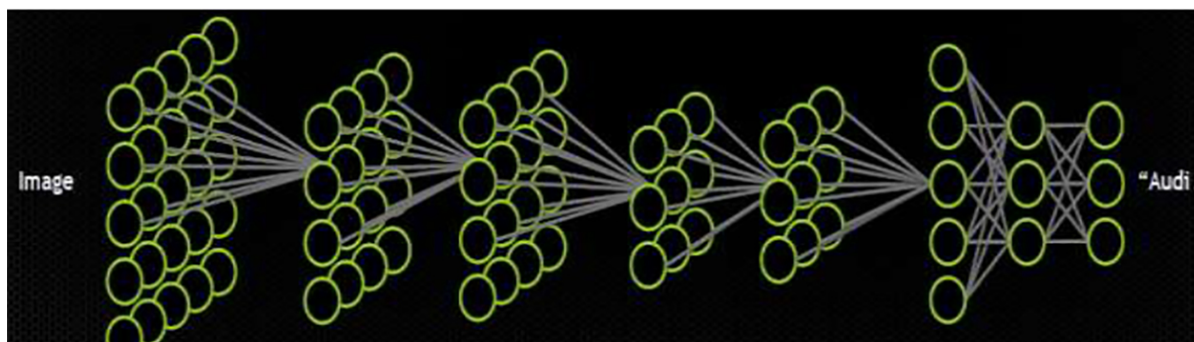


Figure 3.5: The architecture of DL

#### 3.2 Motivation to use Deep Learning

There are several motivating factors that have contributed to the widespread adoption of Deep Learning:

- Large availability of Datasets: The availability of extensive datasets has played a crucial role in enabling Deep Learning. The abundance of labeled data allows deep neural networks to learn and generalize patterns effectively.
- Evolution of graphic equipment (GPU cards): Deep Learning algorithms benefit greatly from parallel processing, and the evolution of powerful GPU cards has significantly

accelerated the training and inference speed of deep neural networks. GPUs excel at performing matrix operations, which are fundamental to Deep Learning computations.

- Reasonably priced equipment: The cost of hardware required for Deep Learning has become more accessible over time. GPU cards, which were once expensive and primarily used in specialized settings, are now more affordable, making Deep Learning more feasible for researchers, developers, and businesses.
- Development of treatment techniques and methods: Deep Learning has witnessed advancements in treatment techniques and methods, such as convolutional neural networks (CNNs) for image recognition and recurrent neural networks (RNNs) for sequential data. These developments have significantly improved the accuracy and performance of Deep Learning models, fueling their popularity. Collectively, these factors have contributed to the motivation and widespread adoption of Deep Learning, empowering its applications across various domains and industries [30].

### 3.3 Application Fields

Deep Learning has demonstrated its efficacy across numerous domains and tasks, showcasing its versatility and impact. Here are several noteworthy instances:

- Image classification: Deep Learning, specifically Convolutional Neural Networks (CNNs), has achieved remarkable accuracy in categorizing images. This breakthrough technology enables applications like object recognition, medical imaging analysis, and autonomous driving.
- Machine translation: Deep Learning has revolutionized machine translation by empowering the development of robust neural machine translation models. These models facilitate cross-language communication and localization, transforming the way we bridge linguistic gaps.
- Game playing (e.g., chess): Deep Learning has made significant strides in game playing, as evident in the accomplishments of Deep Blue and AlphaGo. By comprehending complex strategies and decision-making processes, Deep Learning models can compete at an exceptional level in games such as chess, Go, and poker.
- Facial recognition: Deep Learning has greatly enhanced facial recognition systems by creating robust models capable of accurately identifying individuals from images or video streams. This technology finds applications in security, surveillance, and user authentication.

## Chapter 3. Machine Learning and Deep Learning

---

- **Gesture recognition:** Deep Learning enables the recognition and interpretation of human gestures captured by sensors or cameras. Its applications span sign language recognition, human-computer interaction, and virtual reality, providing new avenues for seamless communication.
- **Speech recognition (speech-to-text conversion):** Deep Learning-based speech recognition systems have made significant strides in accurately transcribing spoken language into written text. Voice assistants, transcription services, and voice-controlled systems greatly benefit from this technology.
- **Video search (research and analysis):** Deep Learning models excel in analyzing and indexing videos based on their content, making it easier to search for specific visual information within extensive video databases. This has diverse applications in video surveillance, media analysis, and content recommendation.
- **Robotics and autonomous vehicles:** Deep Learning plays a vital role in perception and decision-making for robots and self-driving cars. It equips them with the ability to recognize objects, navigate environments, and make real-time decisions based on sensor data.
- **Indexing and searching (e.g., web document search):** Deep Learning techniques have enhanced the efficiency and accuracy of indexing and searching vast amounts of text-based data, such as web pages, documents, and digital archives. As a result, users can access faster and more relevant search results.

These examples exemplify the broad spectrum of applications where Deep Learning has made significant contributions, transforming various fields and pushing the boundaries of what machines can achieve.

### 3.4 Deep Learning Requirements

Deep Learning has certain requirements to achieve optimal performance and results. Here are some key requirements:

- **More data (Large datasets, Big Data):** Deep Learning models thrive on large amounts of labeled data. Having access to extensive datasets allows models to learn more diverse patterns and make accurate predictions. The availability of big data has significantly contributed to the success of Deep Learning.
- **Best learning models (e.g., DNN, CNN, RNN, Autoencoders, etc.):** Deep Learning encompasses a variety of models that are specifically designed for different types of data and tasks.

Models like Deep Neural Networks (DNNs), Convolutional Neural Networks (CNNs), Recurrent Neural Networks (RNNs), and Autoencoders are commonly used in various Deep Learning applications. Selecting the most suitable model architecture is crucial for achieving desired results.

- **Powerful GPU accelerators:** Deep Learning computations involve intensive matrix operations, and these tasks can be significantly accelerated with the use of powerful Graphics Processing Units (GPUs). GPUs, such as the Nvidia Drive™ PX AutoPilot car computer and the Tegra X1 mobile superchip with a 256-core GPU and an 8-core 64-bit CPU, provide the necessary computational power to train and deploy Deep Learning models efficiently. These GPU accelerators can handle the high-dimensional calculations required for Deep Learning algorithms, resulting in faster training and inference times.

These requirements highlight the need for substantial amounts of data, appropriate model architectures, and robust hardware acceleration to maximize the potential of Deep Learning. By meeting these requirements, researchers and practitioners can leverage the full capabilities of Deep Learning algorithms and achieve state-of-the-art results in various applications [30].

### 3.5 ML VS DL

- Deep learning falls under the umbrella of machine learning, a branch of artificial intelligence. While machine learning focuses on enabling computers to make decisions and perform tasks with minimal human intervention, deep learning specifically leverages neural networks inspired by the human brain to enable computers to think and learn.
- In terms of computational requirements, machine learning generally demands less computing power compared to deep learning, which often necessitates more substantial computational resources. Additionally, deep learning models tend to require less ongoing human intervention once they are trained, as they can autonomously learn and adapt from data.
- One notable advantage of deep learning is its ability to analyze and extract insights from complex data types such as images, videos, and unstructured data. This capability sets deep learning apart from traditional machine learning, which may struggle with such data formats.
- Considering the impact of these technologies, career opportunities in machine learning and deep learning are abundant across various industries. Virtually every sector offers career paths involving the application of these techniques to solve problems and drive innovation.

### 4 The Future of AI

The future of AI holds immense potential for transformation across various domains. Here are some key areas that are likely to shape the future of AI:

- **Advancements in Machine Learning:** Machine learning algorithms will continue to evolve, enabling AI systems to learn from larger and more diverse datasets. This will enhance their ability to recognize patterns, make predictions, and perform complex tasks with increased accuracy.
- **Deep Learning and Neural Networks:** Deep learning techniques, which involve training artificial neural networks with multiple layers, have shown remarkable success in various applications. Future developments may involve the creation of even more sophisticated neural network architectures and training methods, leading to improved performance across domains such as image recognition, natural language processing, and robotics.
- **Natural Language Processing (NLP):** NLP is the field of AI that focuses on enabling computers to understand and generate human language. In the future, NLP is likely to advance further, leading to more advanced virtual assistants, translation tools, and chatbots that can understand and communicate in a more natural and nuanced manner.
- **AI in Healthcare:** AI has the potential to revolutionize healthcare by assisting in early disease detection, personalized medicine, drug discovery, and medical image analysis. Future applications may involve AI systems working alongside healthcare professionals to improve diagnostics, treatment plans, and patient outcomes.
- **Autonomous Vehicles:** The development of self-driving cars and other autonomous vehicles is another exciting area of AI. As AI algorithms improve, autonomous vehicles are expected to become safer, more reliable, and more prevalent on our roads. This could lead to significant changes in transportation systems and urban planning.
- **Ethical and Responsible AI:** As AI becomes increasingly integrated into our lives, the importance of ethical and responsible AI practices will grow. Ensuring transparency, fairness, and accountability in AI algorithms will be crucial to address concerns related to bias, privacy, and the impact of AI on jobs and society as a whole.
- **AI and Robotics:** The combination of AI and robotics has the potential to transform industries such as manufacturing, logistics, and agriculture. Future developments may involve the creation of more versatile and adaptable robots that can perform complex tasks in unstructured environments.

### **Chapter 3. Machine Learning and Deep Learning**

---

- **AI and Creativity:** While AI has already made strides in generating art, music, and literature, the future holds the promise of even more creative AI systems. AI could be used to assist and collaborate with artists, musicians, and writers, pushing the boundaries of what is possible in terms of creative expression.

It is important to note that the future of AI is uncertain, and its trajectory will depend on various factors such as technological advancements, societal acceptance, and regulatory frameworks. However, with ongoing research and development, AI is poised to reshape numerous industries and aspects of our daily lives.

## **Chapter 4**

# **Implementation and Experimental Results**

### 1 Introduction

In this chapter, our objective is to delve into the intricacies of our operational methods. We aim to provide a thorough and detailed explanation of how we conduct our work, leaving no stone unturned. Additionally, we will elucidate the various tools and resources we utilize throughout the process, shedding light on their significance and functionality. Moreover, we will meticulously outline the step-by-step procedures involved in the implementation of our strategies, ensuring a comprehensive understanding of the entire process from start to finish. By expanding on these aspects, we aim to provide a comprehensive and insightful exploration of our working methodology in this chapter.

Then, we conduct an empirical evaluation to show its efficiency.

### 2 The Used Programming Language (Python)

Python is a high-level, interpreted, and object-oriented programming language known for its dynamic semantics and easy-to-learn syntax. It supports rapid application development and can be used as a scripting language or for connecting existing components. Python's productivity benefits include fast edit-test-debug cycles and easy debugging due to its exception handling. It also offers a source level debugger for detailed inspection of variables and code execution [31].

### 3 Environment of work

#### (Torch-summary 1.4.5.(2022.3.1))

Torch-summary, formerly known as torchinfo, is a PyTorch package inspired by the original torchsummary package. Its purpose is to provide a summary of a PyTorch model by displaying the number of parameters and the output shape of each layer. This package is versatile and can handle various types of layers, including RNNs, LSTMs, recursive layers, sequentials, module lists, and branching outputs. It allows users to explore model layers by specifying desired depths. Torch-summary, now under the name torchinfo, is actively developed and is compatible with the latest version of Python. You can find the package on PyPI for easy installation [32].

# 4 Development Tools

## 4.1 Anaconda environment:

Anaconda is a free and open-source distribution of Python and R programming languages, designed to streamline package management and deployment. It includes the Python interpreter and a range of packages relevant to machine learning and data science. In Anaconda, an environment refers to a specific folder or directory that contains a curated collection of conda packages and their dependencies. Environments enable separate maintenance and execution of packages without interference between them [33].

## 4.2 Jupyter:

Jupyter is an open-source web application developed by Project Jupyter. It enables users to create and share documents that combine live code, equations, visualizations, and text. The documents created in Jupyter provide an interactive computing environment, allowing users to write and execute code, document their analysis, and share their work with others [34].

## 4.3 VS Code:

Visual Studio Code (VS Code) is a cross-platform source-code editor created by Microsoft using the Electron Framework. It is compatible with Windows, Linux, and macOS. VS Code offers a wide range of features including debugging capabilities, syntax highlighting, intelligent code completion, code snippets, code refactoring tools, and integrated Git support [35].

## 4.4 Workstation:

During our project, we utilized two workstations. The first workstation was dedicated to machine learning tasks and did not require high-end specifications.

**Table 4.1:** workstation-1-

---

Hardware and software	Characteristics
Memory (RAM)	08 Gb
Processor (CPU)	Intel Core i7-6600U CPU 2.60GHz x4
Graphics (GPU)	Intel(R) HD Graphics 520
Operating system	Windows 10 Professionnel 64bits, processeur x64

---

## Chapter 4. Implementation and Experimental Results

---

The data models were trained on three machines (Two for training , one for testing) with the following specifications:

First machines specifications:

**Table 4.2:** workstation-2-

Hardware and software	Characteristics
Memory (RAM)	128GB
Processor (CPU)	Intel Xeon W-3275M
Graphics (GPU)	4x NVIDIA A100 Tensor Core GPUs
Operating system	Linux-based operating system windows
Storage	8TB NVMe SSD

Second machines specifications:

**Table 4.3:** workstation-3-

Hardware and software	Characteristics
Memory (RAM)	512 GB DDR4 ECC RAM (Error-Correcting Code)
Processor (CPU)	Dual Intel Xeon Platinum 8280 processors
Graphics (GPU)	NVIDIA A100 GPUs (40 GB VRAM each)
Operating system	Linux-based operating system Ubuntu
Storage	- 16 TB NVMe SSD- 128 TB HDD .

Third machines specifications: MacBook M2 pro

**Table 4.4:** workstation-4-

Hardware and software	Characteristics
Memory (RAM)	32GB
Processor (CPU)	12-Core
Graphics (GPU)	30-Core
Storage	1TB SSD

### 4.5 FastAPI

FastAPI is a modern and high-performance web framework for creating APIs using Python 3.7+ and leveraging standard Python type hints. It offers several key features that make it stand out:

1. Fast: FastAPI boasts high performance, comparable to frameworks like NodeJS and Go. This is achieved through the utilization of the Starlette framework and Pydantic library.

2. Fast to code: FastAPI enhances development speed by approximately 200 %to 300 %, allowing developers to build features quickly.

3. Fewer bugs: FastAPI reduces human-induced errors by about 40 %, resulting in more robust and reliable code.

4. Intuitive: The framework provides excellent editor support and offers code completion throughout the development process, minimizing debugging time.

5. Easy: FastAPI is designed to be user-friendly and easy to learn, allowing developers to spend less time on reading documentation.

6. Short: FastAPI promotes code minimization and reduces duplication, enabling multiple features from each parameter declaration and leading to fewer bugs.

7. Standards-based: The framework is based on and fully compatible with open standards for APIs such as OpenAPI (previously known as Swagger) and JSON Schema.

Overall, FastAPI combines high performance, ease of use, and adherence to standards, making it a powerful choice for building efficient and scalable APIs in Python.

## 5 Used libraries



Figure 4.1: Python libraries

### 5.1 OS:

The `os` module is used for file and directory management tasks. It enables operations such as creating, renaming, and deleting directories. It provides functions to retrieve the current working directory and change it. Additionally, the `os` module facilitates file copying between directories [36].

### 5.2 NumPy:

NumPy is a Python library for scientific computing that offers a multidimensional array object, derived objects, and a wide range of functions for efficient array operations. It supports mathematical operations, array manipulation, sorting, I/O operations, linear algebra, statistical calculations, random simulation, and more [37].

### 5.3 pandas (pd):

The open-source data analysis and manipulation program pandas is quick, strong, adaptable, and simple to use. It offers a rich range of functions for working with structured data and is built on the Python programming language [38].

### 5.4 matplotlib.pyplot (plt):

matplotlib.A tool called pyplot offers a MATLAB-like interface for matplotlib plotting. It has a number of methods that make it easier to create plots. In addition to opening figures on the screen and acting as a GUI manager for figures, it enables interactive plot development. For simple programmatic plot creation and interactive charts, pyplot is extremely helpful [39].

### 5.5 Seaborn

Seaborn is a Python library for data visualization that builds upon matplotlib. It offers a user-friendly interface for creating visually appealing and insightful statistical graphics. Seaborn is a valuable tool for data exploration and comprehension. It enables users to generate various types of plots, including line plots, scatter plots, bar plots, box plots, violin plots, heatmaps, and more [40].

### 5.6 Keras

Keras is a Python library that sits on top of the TensorFlow platform<sup>3</sup>, serving as a high-level API. It simplifies the process of creating and training deep learning models, emphasizing fast

debugging, elegant and concise code, easy maintenance, and efficient deployment. Keras offers crucial abstractions and foundational components for developing and delivering machine learning solutions with rapid iteration velocity [41].

### 5.7 Joblib

Joblib is a collection of tools designed to facilitate lightweight pipelining in Python. It offers useful features for storing and retrieving Python objects that utilize NumPy data structures in an efficient manner. Joblib excels at handling the serialization and deserialization of NumPy arrays, and it doesn't mandate the installation of NumPy. Additionally, Joblib provides the option to use `python-lz4` as a faster compression alternative to `zlib` and `gzip` for serialization purposes. Furthermore, Joblib offers the option to utilize `psutil` as an optional dependency to address memory leaks in parallel worker processes [42].

### 5.8 sklearn

Scikit-learn, also known as `sklearn`, is a popular machine learning library for Python. It provides a wide range of tools and algorithms for tasks such as classification, regression, clustering, and dimensionality reduction. Scikit-learn is built on top of other scientific computing libraries in Python, such as NumPy, SciPy, and matplotlib.

Here are some key features of scikit-learn:

1. **Consistent API:** Scikit-learn provides a consistent and intuitive API for different machine learning algorithms, making it easier to experiment and switch between different models.
2. **Preprocessing:** It offers various preprocessing techniques for handling data before training a model. This includes data normalization, encoding categorical variables, and handling missing values.
3. **Supervised Learning:** Scikit-learn includes a wide range of supervised learning algorithms, including linear regression, logistic regression, support vector machines (SVM), decision trees, random forests, and gradient boosting methods like XGBoost and LightGBM.
4. **Unsupervised Learning:** It provides several algorithms for unsupervised learning tasks, such as clustering (K-means, DBSCAN), dimensionality reduction (PCA, t-SNE), and outlier detection.
5. **Model Evaluation:** Scikit-learn offers tools for evaluating model performance using various metrics, cross-validation techniques, and hyperparameter tuning. It also supports model selection and ensemble methods.
6. **Integration:** Scikit-learn integrates well with other libraries in the Python ecosystem, making it easy to combine with data manipulation libraries like pandas and visualization libraries

like matplotlib and seaborn.

Overall, scikit-learn is a powerful and versatile library for machine learning tasks in Python, and it is widely used by researchers and practitioners for building and evaluating machine learning models [43].

## 6 Data Description

### 6.1 Dataset-plant diseases

This stage, overview and analysis of a dataset consisting of approximately 87,000 RGB images of healthy and diseased crop leaves. The dataset is categorized into 38 different classes, representing various types of crop diseases. The dataset has undergone offline augmentation from the original dataset to enhance its diversity and ensure better model performance. The dataset is further divided into training and validation sets with an 80/20 ratio, preserving the directory structure. Additionally, a separate directory is created for prediction purposes, containing 33 test images.

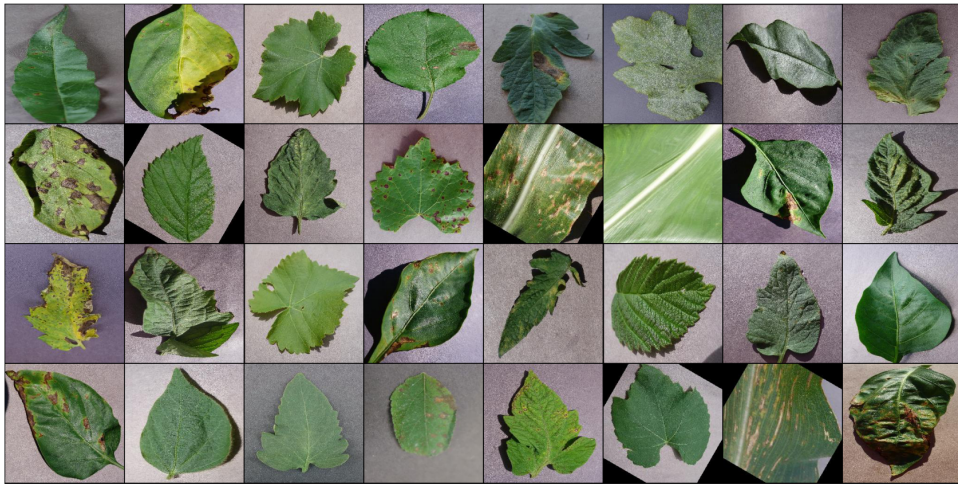
- Number of Images: Approximately 87,000 RGB images.
- Classes: The dataset is categorized into 38 different classes, representing various types of crop diseases.
- Image Type: RGB (Red, Green, Blue) images.
- Augmentation: The dataset has undergone offline augmentation to increase its diversity and improve the model's ability to generalize.
- Data Split: The dataset is split into a training set and a validation set, with an 80/20 ratio, respectively.
- Test Set: A separate directory containing 33 test images is created for prediction purposes.

The details of this dataset are presented in Table 4.1 The formed dataset contains the following datasets:

datasets:

**Table 4.5:** Farmy dataset

• Tomato__Late_blight	1851
• Tomato__healthy	1926
• Grape__healthy	1692
• Orange__Haunglongbing_(Citrus_greening)	2010
• Soybean__healthy	2022
• Squash__Powdery_mildew	1736
• Potato__healthy	1824
• Corn_(maize)__Northern_Leaf_Blight	1908
• Tomato__Early_blight	1920
• Tomato__Septoria_leaf_spot	1745
• Corn_(maize)__Cercospora_leaf_spot Gray_leaf_spot	1642
• Strawberry__Leaf_scorch	1774
• Peach__healthy	1728
• Apple__Apple_scab	2016
• Tomato__Tomato_Yellow_Leaf_Curl_Virus	1961
• Tomato__Bacterial_spot	1702
• Apple__Black_rot	1987
• Blueberry__healthy	1816
• Cherry_(including_sour)__Powdery_mildew	1683
• Peach__Bacterial_spot	1838
• Apple__Cedar_apple_rust	1760
• Tomato__Target_Spot	1827
• Pepper,_bell__healthy	1988
• Grape__Leaf_blight_(Isariopsis_Leaf_Spot)	1722
• Potato__Late_blight	1939
• Tomato__Tomato_mosaic_virus	1790
• Strawberry__healthy	1824
• Apple__healthy	2008
• Grape__Black_rot	1888
• Potato__Early_blight	1939
• Cherry_(including_sour)__healthy	1826
• Corn_(maize)__Common_rust_	1907
• Grape__Esca_(Black_Measles)	1920
• Raspberry__healthy	1781
• Tomato__Leaf_Mold	1882
• Tomato__Spider_mites Two-spotted_spider_mite	1741
• Pepper,_bell__Bacterial_spot	1913
• Corn_(maize)__healthy	1859



**Figure 4.2:** Some samples from our Used dataset

### 6.2 Dataset- Soil Fertility analysis:

The dataset was constructed by combining data on rainfall, climate, and fertilizer from existing sources in India. By leveraging this dataset, users can build a model that takes into account these factors and provides recommendations on the optimal crops to cultivate in a particular farm. This dataset serves as a valuable resource for developing agricultural decision support systems and optimizing crop selection processes. Data fields:

**Table 4.6:** Data fields

N	ratio of Nitrogen content in soil
P	ratio of Phosphorous content in soil
K	ratio of Potassium content in soil
temperature	temperature in degree Celsius
humidity	relative humidity in %
ph	ph value of the soil
rainfall	rainfall in mm

We obtained the dataset used for training our model from Kaggle, specifically for the purpose of Crop Recommendation [44]:

## Chapter 4. Implementation and Experimental Results

---

**Table 4.7:** Crop Recommendation

N	P	K	temperature	humidity	ph	rainfall	label
90	42	43	20.879744	82.002744	6.502985	202.935536	rice
85	58	41	21.770462	80.319644	7.038096	226.655537	rice
60	55	44	23.004459	82.320763	7.840207	263.964248	rice
74	35	40	26.491096	80.158363	6.980401	242.864034	rice
78	42	42	20.130175	81.604873	7.628473	262.717340	rice
...	...	...	...	...	...	...	...
107	34	32	26.774637	66.413269	6.780064	177.774507	coffee
99	15	27	27.417112	56.636362	6.086922	127.924610	coffee
118	33	30	24.131797	67.225123	6.362608	173.322839	coffee
117	32	34	26.272418	52.127394	6.758793	127.175293	coffee
104	18	30	23.603016	60.396475	6.779833	140.937041	coffee

### 6.3 Used Algorithms

#### plant diseases

##### 6.3.1 Used model(ResNet-9)

There are several motivations for using deep learning: ResNet-9 is a variant of the Residual Neural Network (ResNet) architecture used for image classification in deep learning. It was introduced by researchers from Microsoft Research in 2015 and has since become a popular choice due to its ability to train very deep neural networks effectively. ResNet-9 follows the standard ResNet design with CONV-Layers, batch normalization, ReLU activation, and pooling layers. It has demonstrated impressive performance on image classification tasks while maintaining a balance between model complexity and computational efficiency [45].

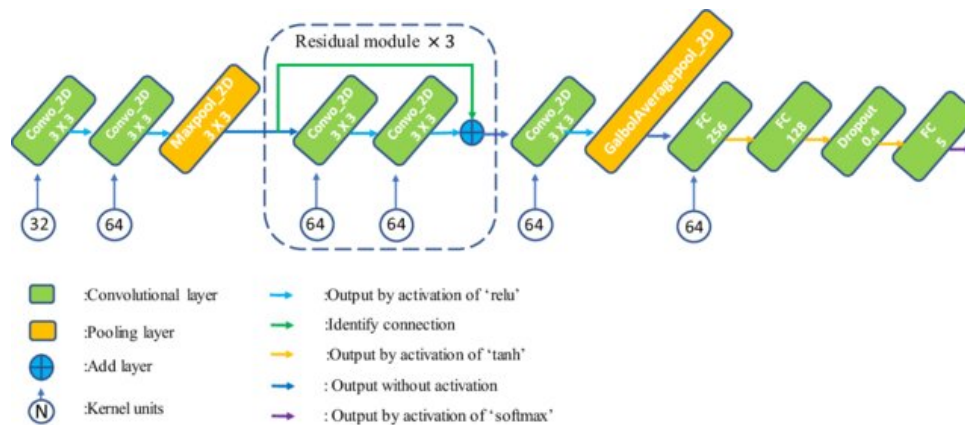


Figure 4.3: Architecture of Resnet-9 model [3]

#### Crop Recommendation

##### 6.3.2 Decision Tree classifier

decision tree classifier is a non-parametric supervised learning algorithm that can be utilized for both classification and regression tasks. Its objective is to construct a model that predicts the value of a target variable by learning straightforward decision rules derived from the features present in the data. Each decision tree can be viewed as an approximation of the target variable using a piecewise constant function.

In Python, the scikit-learn library offers a DecisionTreeClassifier class that implements the decision tree algorithm. This class provides a convenient and efficient way to create decision tree models for classification problems [43].

### 6.3.3 Naive Bayes

Naive Bayes is a straightforward technique used for constructing classifiers in supervised machine learning. It assigns class labels to instances represented as feature vectors, where the class labels are chosen from a finite set. Naive Bayes is commonly employed for classification tasks, particularly in text classification applications.

Python's scikit-learn library includes a Naive Bayes classifier that implements the Naive Bayes algorithm. This classifier can be used to build models and make predictions based on the probabilistic principles of Naive Bayes [43].

### 6.3.4 Support Vector Machines

Support Vector Machines (SVMs) are a group of supervised learning algorithms utilized for tasks such as classification, regression, and outliers detection. SVMs offer several advantages, including their effectiveness in high-dimensional spaces and their ability to handle cases where the number of dimensions exceeds the number of samples.

Python's scikit-learn library provides an SVM classifier that implements the SVM algorithm. This classifier is capable of creating models for classification, regression, and outlier detection based on the principles of SVM [43].

### 6.3.5 Logistic Regression

Correct. In machine learning, the nature of the dependent variable distinguishes between regression and classification problems. Regression problems involve predicting a continuous and typically unbounded output. On the other hand, classification problems involve assigning data points to discrete classes.

Classification problems can be further categorized into two main types:

1. Binary or binomial classification: This type of classification involves predicting between exactly two classes. Common examples include distinguishing between true and false, positive and negative, or 0 and 1.
2. Multiclass or multinomial classification: In this type, the classification task involves selecting from three or more classes for the output variable. The classes are mutually exclusive, and the model aims to assign each data point to one of the available classes [46].

### 6.3.6 Random Forest Classifier

A random forest classifier is a popular machine learning algorithm that acts as a meta estimator. It builds multiple decision tree classifiers on different subsets of the dataset and utilizes averaging

## Chapter 4. Implementation and Experimental Results

---

to enhance predictive accuracy and mitigate overfitting. Random forests are frequently employed for various tasks, including classification and regression.

During the training process, a random forest constructs numerous decision trees. Each tree is built on a different subset of the training data, promoting diversity among the individual trees. When making predictions, the random forest combines the outputs of these trees to determine the final result. In classification tasks, the class chosen by the majority of trees is selected as the output of the random forest.

Random forests offer several advantages, such as their ability to handle high-dimensional data, assess feature importance, and reduce the risk of overfitting. Due to their effectiveness and versatility, random forests are widely used in machine learning for diverse applications [43].

### 6.3.7 Recurrent Neural Network

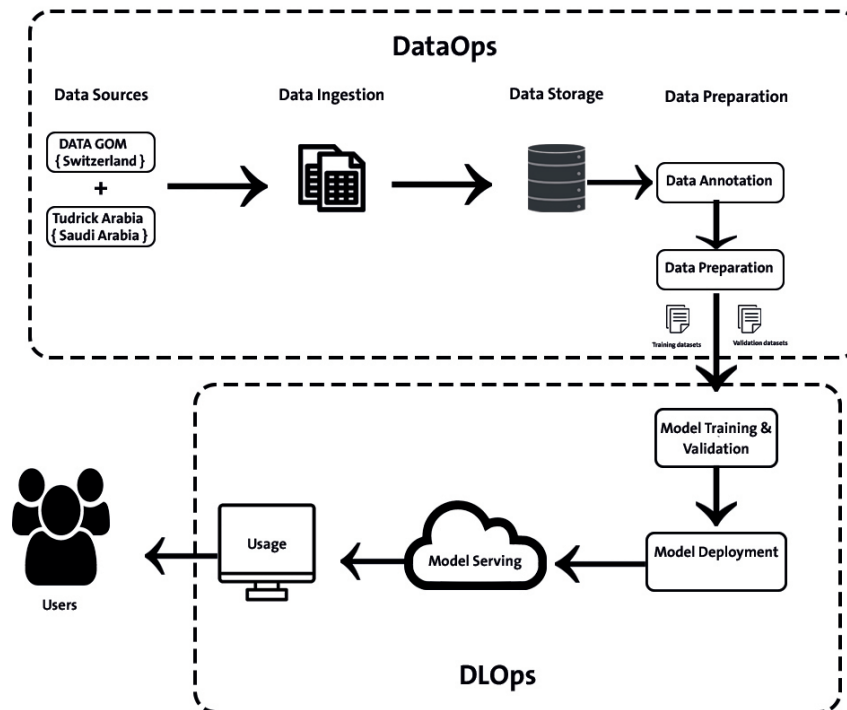
A Recurrent Neural Network (RNN) is a type of artificial neural network that is specifically designed for processing sequential or time series data. RNNs are widely used in various applications such as language translation, natural language processing (NLP), speech recognition, and image captioning. They are utilized in popular voice assistants like Siri and Alexa. RNNs are particularly effective in modeling and predicting sequential data, mimicking the way human brains process information. In essence, RNNs excel in producing predictions and insights from sequential data that may not be achievable using other algorithms [47].

## 7 Experimentation

### 7.1 plant diseases:

During the exploratory data analysis, the following aspects were investigated:

1. **Class Distribution:** The distribution of images across the 38 different classes was analyzed to identify any class imbalance issues that might affect model training and performance.
2. **Image Size:** The dimensions (width and height) of the images were examined to ensure consistency and identify any variations in size that might require preprocessing or resizing.
3. **Image Quality:** The quality of the images, including color balance, lighting conditions, and clarity, was assessed to determine the overall suitability of the dataset for training a model.

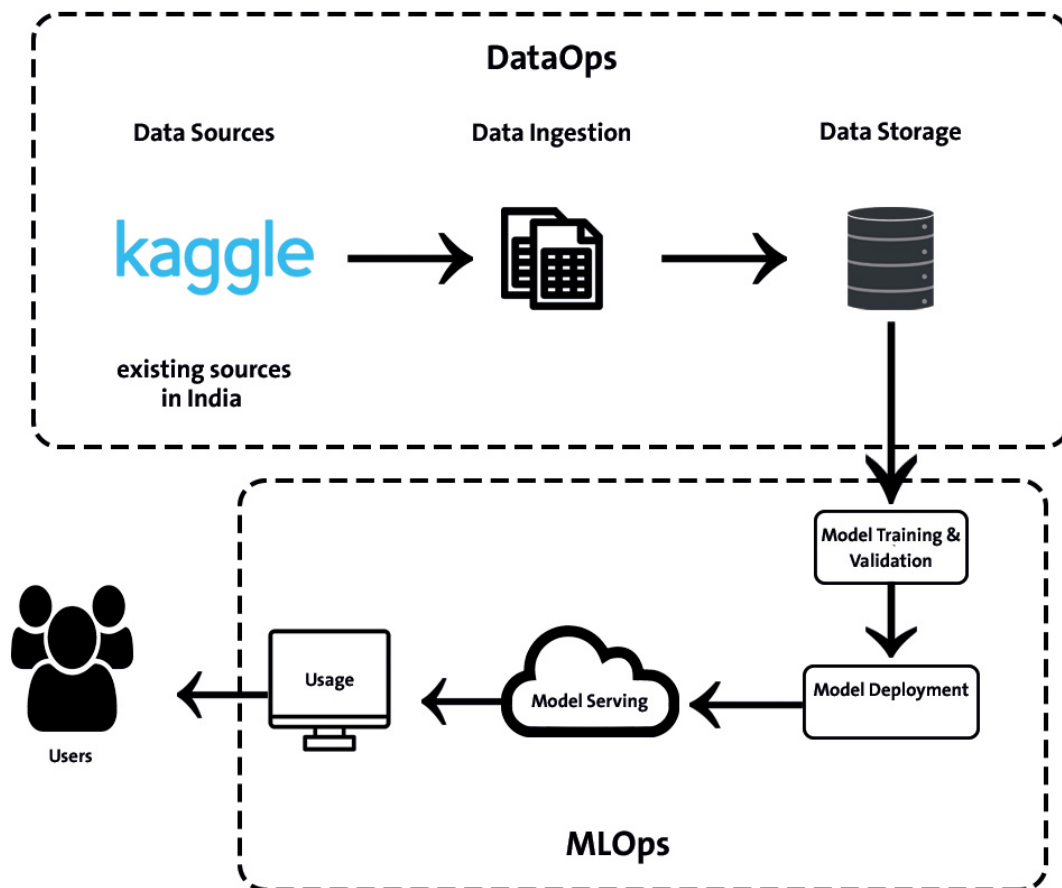


**Figure 4.4:** Crop Recommendation

4. Augmentation Techniques: The specific offline augmentation techniques applied to the original dataset were examined to understand the transformations and variations introduced to the images.
5. Training and Validation Sets: The dataset is divided into training and validation sets with an 80/20 ratio, respectively. The preservation of the directory structure ensures that the data distribution and class representation remain consistent across both sets. This division allows for model training on the training set and evaluation on the validation set to assess the model's performance and generalization ability.
6. Test Set: A separate directory containing 33 test images is created for prediction purposes. These images are distinct from the training and validation sets and serve as an independent evaluation set to measure the model's performance on unseen data.
7. This dataset of approximately 87,000 RGB images of healthy and diseased crop leaves provides a valuable resource for training and evaluating models in the field of crop disease

classification. The dataset's diverse range of classes, augmented data, and preservation of directory structure for training and validation sets make it suitable for building robust machine learning models. The inclusion of a separate test set further enables accurate assessment of model performance on unseen data.

### 7.2 Crop Recommendation:



**Figure 4.5:** Crop Recommendation

To create a machine learning model that classifies neighboring areas and arable plants based on the characteristics of the area, you can follow these procedures:

## Chapter 4. Implementation and Experimental Results

---

1. **Data Collection:**The dataset was constructed by combining data on rainfall, climate, and fertilizer from existing sources in India.
2. **Data Preprocessing:** Clean and preprocess the collected data. This involves handling missing values, normalizing numerical variables, encoding categorical variables, and splitting the data into training and testing sets.
3. **Model Selection:** To measure model performance, we use mutual verification with five folds. We use Four folds for training, the remaining folds are used for testing. Moreover, models Support Vector Machines (SVM) and Decision Tree Classifier and Naive Bayes , Logistic Regression ,Random Forest Classifier ,in addition to Recurrent Neural Network (RNN) , where they are particularly effective in modeling and forecasting sequenced data.
4. **Model Evaluation:** After applying the algorithms, the following results were obtained and observed in Crop Recommendation:

**Table 4.8:** Obtained Accuracy

Decision Tree Classifier	90 %
Naive Bayes	99,09 %
Support Vector Machines (SVM)	97,72 %
Logistic Regression	95,22 %
Random Forest Classifier	99,00 %
RNN	96,77 %

5. **Model service:** We set up dedicated server to host the device Learning models and predictions. FastAPI was used to create an app software which accepts input data and return predictions.
6. **Users:** Once the data processing is complete, the application is ready to be deployed and made available to users.

## 8 Discussion

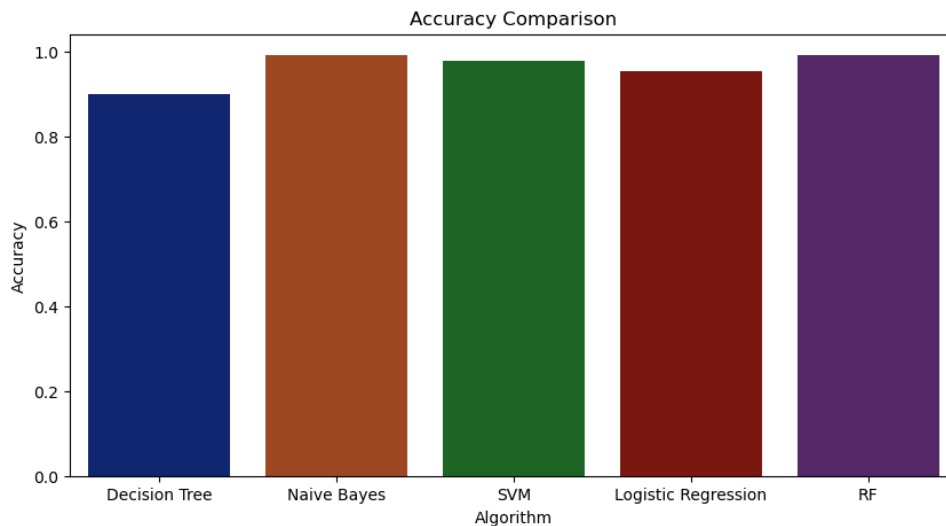
### 8.1 plant diseases:

In our plant disease detection model, we utilized the ResNet-9 architecture as our deep learning model. After training and evaluating the model, we achieved the following accuracy:

**Table 4.9:** Obtained Accuracy

We got an accuracy of 99.2 %
------------------------------

### 8.2 Crop Recommendation:



**Figure 4.6:** Accuracy Comparison on Crop recommendation

Based on the obtained results, we relied on training our model using the Naive Bayes algorithm. We chose to rely on training our model using the Naive Bayes algorithm because it demonstrated the highest accuracy among the other algorithms tested.

### 9 Deep Learning and Smart Agriculture Comprehensive Review

Deep Learning DL becomes one of the most popular sub-field of IA and ML, especially in speech recognition, computer vision, and some other interesting topics. Its success is motivated by three factors: the increased amount of available data, the improvement and the lowest cost of hardware and software, the increased chip processing abilities (e.g., GPU units). The application of deep learning approach proposed by researchers has yielded surprising results in many fields of research, including: computer vision [48] [49], image processing [50] [51], object detection [52] [53], network optimization [53], handwritten digits and character recognition [54] [55], sensor networks [56] [57], sentiment analysis [58], system security [59], Drowsiness Detection System [60], Diabetes Detection [51]. The DL approach gives better results in terms of accuracy but needs massive data.

Innovative technologies are used in the developing field of "smart agriculture" to enhance farming methods. Here are some comprehensive reviews of smart agriculture: "Recent Advancements and Challenges of AIoT Application in Smart Agriculture: A Review": This paper presents a systematic literature review of AIoT to highlight the current progress, its applications, and its advantages in smart agriculture [61]. "A comprehensive review of Data Mining techniques in smart agriculture": This paper reviews ongoing studies and research on smart agriculture, focusing on data mining techniques [62]. "Smart Farming Using Artificial Intelligence, the Internet of Things, and Robotics: A Comprehensive Review": This book chapter discusses the urgent need to stabilize the field of agriculture and provides a comprehensive review of the applications of AI, IoT, and robotics in smart farming [63]. "Smart Farming Using Artificial Intelligence, the Internet of Things, and Robotics: A Comprehensive Review": This review summarizes the various applications of AI, IoT, and robotics in various phases of agriculture [64]. "Understanding technology acceptance in smart agriculture: A systematic review of empirical research in crop production" : This paper presents a systematic review of technology acceptance in smart agriculture, focusing on decision support in crop farming [65].

### 10 Interface

In this section, we present our objective of designing and creating a user-friendly interface that aims to improve the usability and overall user experience of smart farming. The interface description encompasses various aspects such as visual design, interactive elements, and system functions. Our aim is to provide a comprehensive overview of the interface's features and capabilities, ensuring that users can easily comprehend and utilize the system effectively.

The first thing we talk about is the home screen which has Logo app called "Green Era":



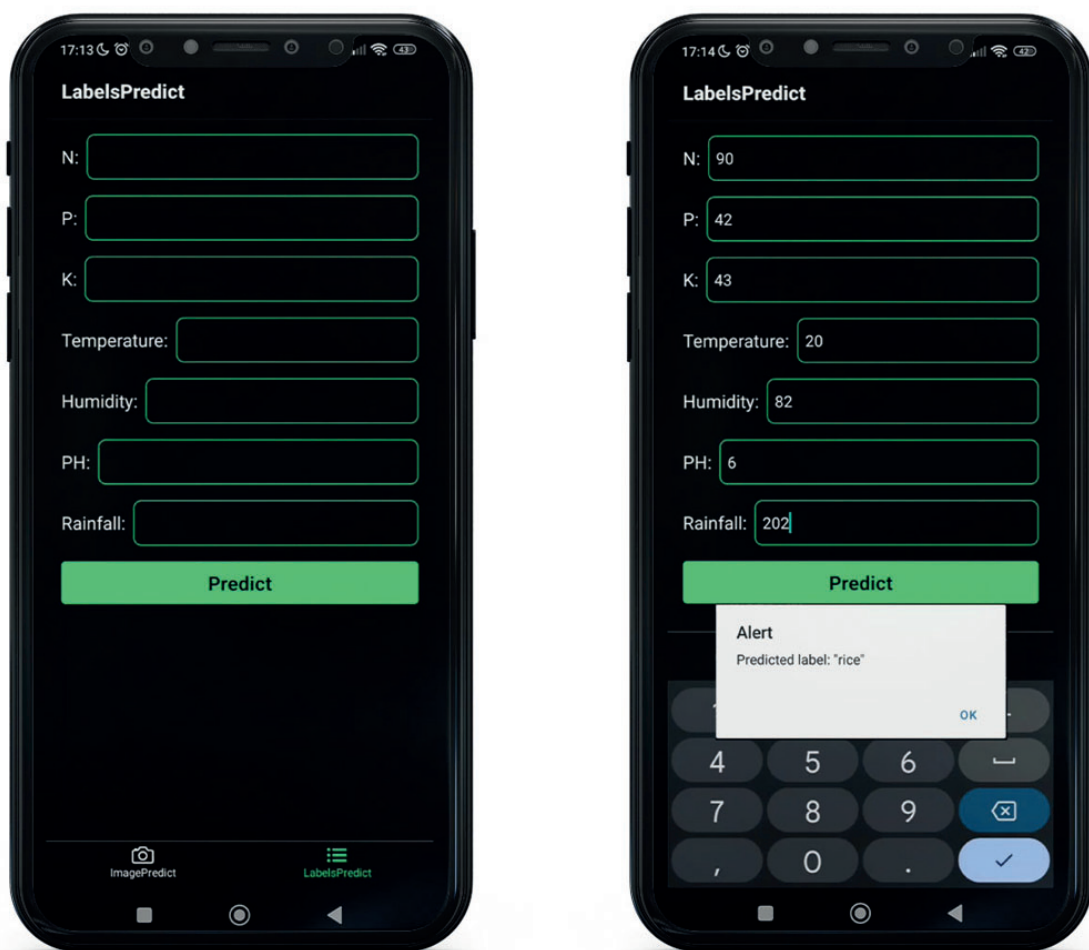
**Figure 4.7:** Home Screen

Our application revolves around two primary functions: plant disease discovery and crop recommendation. Below are some screenshots showcasing various aspects of our app, including input forms and data entry, as well as the display of information and results.

### 10.1 Interface of Crop Recommendation

In this section, users can input the following data: N: Ratio of Nitrogen , P: Ratio of Phosphorous, K: Ratio of Potassium , Temperature: Temperature in degrees Celsius, Humidity: Relative humidity in %, pH: pH value of the soil, Rainfall: Rainfall in (mm).

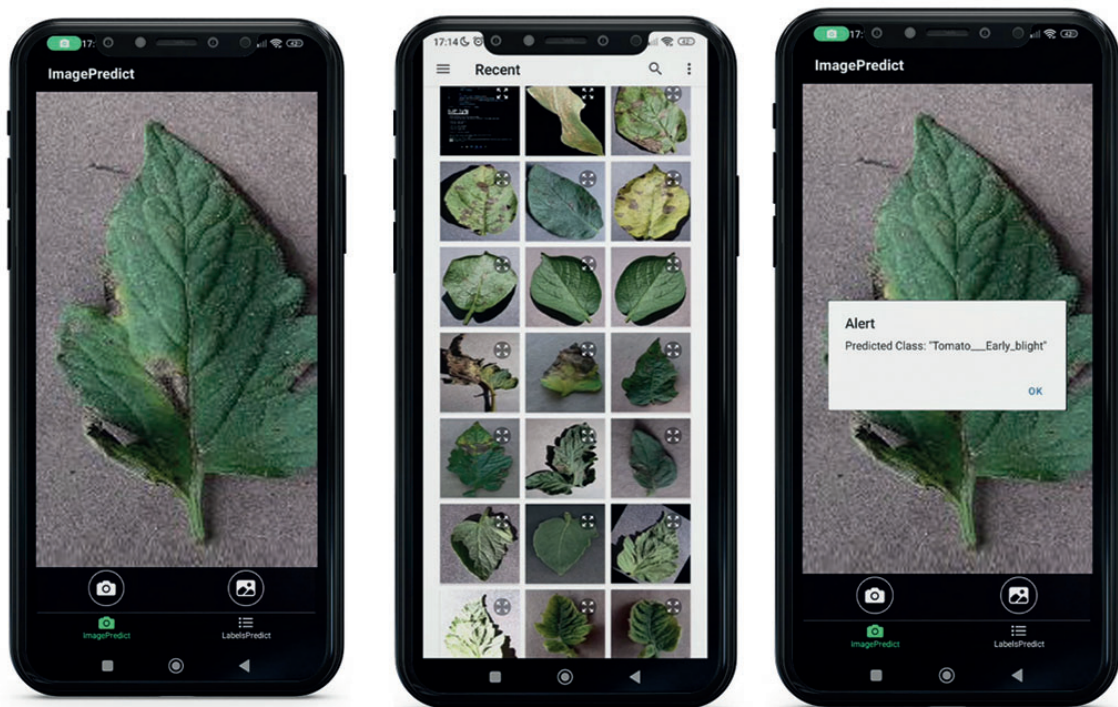
To test this function, we utilized data from our dataset, and based on the input provided, the predicted label was "rice." This is illustrated in the figure below:



**Figure 4.8:** Input and Data Entry and Results of Crop Recommendation

### 10.2 Interface of Plant Disease Discovery

For the plant disease discovery function, we have implemented two options. The first option allows users to take a photograph of the plant using their device's camera. The second option enables them to upload an image from their photo gallery. Subsequently, the system analyzes the image and provides the examination result. The following figure illustrates an example of one of the tomato diseases identified by the system.



**Figure 4.9:** Input and Data Entry and Results of Plant Disease Discovery

## **General Conclusion**

In conclusion, Our exploration of the domain of smart farming has been a source of both knowledge and fulfillment. We embarked on this project with a mission to explore the potential of technology in revolutionizing agriculture and addressing the challenges faced by farmers worldwide. In our discussions, we emphasized the significance of agriculture in ensuring food security and its vital role in the global economy. We delved into the context of agriculture in Algeria, recognizing its immense importance as a sector that contributes to the nation's growth and sustenance.

A vast array of opportunities were revealed by our investigation into smart agriculture. We found that many nations around the world have embraced technological improvements to improve productivity and optimize farming techniques. We paid special attention to soil fertility analysis and plant disease control since we understood how important these factors were in assuring healthy crops and abundant yields. In our quest for knowledge, we also researched the fields of deep learning and machine learning, understanding their unique qualities. With this knowledge, we imagined a project that would leverage these technologies to track plant diseases and propose appropriate crops. The implementation of our project was successful, giving us experimental results as follows 99.2% accuracy for detecting plant diseases using ResNet-9 and 99.09% in Crop Recommendation using Naive Bayes algorithm. As students, our engagement in this project has granted us invaluable benefits. We have gained hands-on experience in applying theoretical concepts to real-world scenarios. Our understanding of agriculture and technology

## **General Conclusion**

---

has deepened, equipping us with practical skills that can be applied in the professional realm. Moreover, our project has fostered teamwork, problem-solving, and critical thinking abilities, which are indispensable in any endeavor we undertake.

However, we encountered certain constraints throughout our journey. The most prominent obstacle we faced was the scarcity of reliable data on agriculture in Algeria. This lack of accessible information compelled us to act as data hunters, gathering relevant data from external sources. While this posed a challenge, it also served as a reminder of the importance of data collection and management in shaping effective agricultural strategies.

The prospects for this initiative in the future are bright. There is enormous potential for the integration of smart farming practices on a broader scale as technology develops. Our initiative acts as a foundation, providing insights into the future possibilities. We anticipate the development of comprehensive smart agricultural systems that can be customized to the particular requirements of various locations and nations with future research and development.

Our research in smart farming has given us a thorough awareness of its advantages and possibilities, so to speak. We have seen firsthand how technology can improve resource efficiency, empower farmers, and promote sustainable farming practices. Smart farming is not merely a concept; it is a pathway towards a future where technology and nature harmoniously coexist, ensuring a prosperous and food-secure world.

# Bibliography

- [1] Persado. Artificial intelligence vs. machine learning vs. data science, 2021. Accessed on May 18, 2023.
- [2] Tahar Mehenni. *Introduction to ML*. Department of Computer Science, Faculty of Mathematics and Informatics, Mohamed Boudiaf University of M'sila, 2021.
- [3] Xiaojun Li, Hongpeng Wang, Weixuan Zhang, and et al. Diagnosis of rotor demagnetization and eccentricity faults for ipmsm based on deep cnn and image recognition. *ResearchGate*, 2022.
- [4] World Bank. Agriculture overview. <https://www.worldbank.org/en/topic/agriculture/overview>, Accessed April 26, 2023.
- [5] First Author and Last. Article title. *Journal of Economic Perspectives*, 28(1):121–146, Winter 2014.
- [6] First Author and Last. The importance of agriculture in the economy: Impacts from covid-19. *PMC*, 2021.
- [7] International Atomic Energy Agency. Applications of nuclear techniques in agriculture. Technical Report TECDOC-1781, International Atomic Energy Agency, Vienna, Austria, 2016.

## Bibliography

---

- [8] HowMuch.net. The role of agriculture around the world, 2019.
- [9] The World Bank. World development indicators, 2023.
- [10] Presidency of the Republic of Algeria. El mouradia palace. <https://www.el-mouradia.dz/ar/president/63fe30f5843b29001d2428f1>, Accessed 26 Apr. 2023.
- [11] The Global Economy. Share of agriculture in algeria. [https://www.theglobaleconomy.com/Algeria/Share\\_of\\_agriculture/](https://www.theglobaleconomy.com/Algeria/Share_of_agriculture/), accessed on 2023-04-26.
- [12] Direction des Statistiques Agricoles et des Systèmes d'Information. Serie b 2019, 2019.
- [13] Food and Agriculture Organization of the United Nations. *The State of Food and Agriculture 2002*. FAO, 2002.
- [14] Amjad Ali, Zakir Ullah, Mukhtar Ahmad, and Syed Adnan Ali Shah. Smart farming applications on agriculture. *ResearchGate*, 2021.
- [15] Muhammad Adeel, Muhammad Asad Ullah, and et al. A comprehensive review on autonomous vehicles: Trends, challenges, and perspectives. *Big Data and Cognitive Computing*, 5(2):21, 2021.
- [16] World Bank Blogs. Climate-smart agriculture: Lessons from africa for the world. <https://blogs.worldbank.org/nasikiliza/climate-smart-agriculture-lessons-from-africa-for-the-world>, Accessed 2023.
- [17] John Cook, Dana Nuccitelli, and et al. Quantifying the consensus on anthropogenic global warming in the scientific literature. *Proceedings of the National Academy of Sciences*, 113(37):E5324–E5331, 2016.
- [18] U.S. Department of Agriculture, Agricultural Research Service. Crop Production and Protection. <https://www.ars.usda.gov/crop-production-and-protection/>. [Accessed May 2, 2023].
- [19] U.S. Department of Agriculture, Agricultural Research Service. Monitoring and Mitigating the Spread of Plant Disease. <https://www.ars.usda.gov/research/annual-report-on-science-accomplishments/fy-2020/monitoring-and-mitigating-the-spread-of-plant-disease/>, 2020. [Accessed May 2, 2023].

## Bibliography

---

- [20] Qiu-Yun Jenny Xiang and Steven E. Ruzin. An overview of plant organogenesis: the challenge of producing complex multicellular structures in plants. *Plant Methods*, 17(1):30, 2021.
- [21] Ryota Kanai. A theoretical model of animal consciousness. *Proceedings of the National Academy of Sciences*, 118(8):e2022239118, 2021.
- [22] S. S. Harapan, A. Wagner, A. Yufika, and et al. Covid-19 vaccine acceptance and hesitancy in low and middle-income countries. *Vaccine*, 39(2021):4733–4741, 2021.
- [23] Flatiron School. Deep learning vs. machine learning, month year.
- [24] Machine learning: Tout savoir. <https://datascientest.com/machine-learning-tout-savoir>, 2022. Accessed on 9th May 2023.
- [25] ML-Ops.org. Motivation for ml ops. <https://ml-ops.org/content/motivation>, 2022. Accessed on 9th May 2023.
- [26] ML-Ops.org. Motivation, 2022. Accessed on 9th May 2023.
- [27] Packt Publishing. The motivation behind ml, 2022. Accessed on 9th May 2023.
- [28] Persado. What is motivation ai?, 2022. Accessed on 9th May 2023.
- [29] Machine Learning Mastery. Why get into machine learning?, 2022. Accessed on 9th May 2023.
- [30] Said Gadri. *Introduction to AI*. Department of Computer Science, Faculty of Mathematics and Informatics, Mohamed Boudiaf University of M’sila, 2022.
- [31] Python Software Foundation. Blurb. <https://www.python.org/doc/essays/blurb/>, 2023. Accessed on May 16, 2023.
- [32] PyPI. torch-summary. <https://pypi.org/project/torch-summary/>, 2023. Accessed on May 16, 2023.
- [33] Anaconda, Inc. Anaconda Server - Creating and Managing Environments. <https://server-docs.anaconda.com/en/latest/user/environment.html>, 2023. Accessed: 21 May 2023.
- [34] Project Jupyter. Jupyter Project. <https://jupyter.org/>, 2023. Accessed: 21 May 2023.

## Bibliography

---

- [35] Microsoft Corporation. Visual Studio Code. <https://code.visualstudio.com/>, 2023. Accessed: 21 May 2023.
- [36] GeeksforGeeks. Python - Directory Management. <https://www.geeksforgeeks.org/python-directory-management/>, 2023. Accessed: May 21, 2023.
- [37] NumPy Documentation. <https://numpy.org/doc/stable/>, 2023. Accessed: May 21, 2023.
- [38] Pandas Development Team. Pandas Documentation, 2023.
- [39] Matplotlib Development Team. Matplotlib - Introduction to Pyplot. <https://matplotlib.org/stable/tutorials/introductory/pyplot.html>, 2023. Accessed: 21 May 2023.
- [40] Michael Waskom. Seaborn: statistical data visualization. <https://seaborn.pydata.org/>, 2023.
- [41] Keras Team. Keras: Deep learning library for Python. <https://keras.io/about/>, 2023.
- [42] Gaël Varoquaux, Lars Buitinck, Gilles Louppe, Olivier Grisel, Fabian Pedregosa, Andreas Mueller, and Édouard Duchesnay. joblib: Python library to save and load python objects to/from disk. <https://pypi.org/project/joblib/>, 2023.
- [43] scikit-learn. <https://scikit-learn.org/stable/>. Accessed: May 22, 2023.
- [44] Raza, Nabeel. Crop Recommendation Project. <https://www.kaggle.com/code/nabeelraza/crop-recommendation-project/notebook>, 2023. Accessed: 21 May 2023.
- [45] Kaiming He, Xiangyu Zhang, Shaoqing Ren, and Jian Sun. Deep residual learning for image recognition. In *Proceedings of the IEEE conference on computer vision and pattern recognition (CVPR)*, 2016.
- [46] Real Python. Logistic regression in python. <https://realpython.com/logistic-regression-python/>, 2023.
- [47] BuiltIn. Recurrent Neural Networks and LSTM. <https://builtin.com/data-science/recurrent-neural-networks-and-lstm>, 2023. Accessed: 21 May 2023.

## Bibliography

---

- [48] Christian Szegedy, Wei Liu, Yangqing Jia, Pierre Sermanet, Scott Reed, Dragomir Anguelov, Dumitru Erhan, Vincent Vanhoucke, and Andrew Rabinovich. Going deeper with convolutions. In *Computer Vision and Pattern Recognition*, pages 1–9, 2015.
- [49] Ross Girshick. Fast R-CNN. In *IEEE International Conference on Computer Vision*, pages 1440–1448, 2015.
- [50] Alex Krizhevsky, Ilya Sutskever, and Geoffrey E. Hinton. Imagenet classification with deep convolutional neural networks. In *International Conference on Neural Information Processing Systems*, pages 1097–1105, 2012.
- [51] G. Said and N. Erich. Building best predictive models using ml and dl approaches to categorize fashion clothes. In *Proceedings of the 19th International Conference on Artificial Intelligence and Soft Computing (ICAISC)*, Zakopane, Poland, October 2020. Springer. H5-index = 20.
- [52] S. Gadri and N.E. Adouane. Efficient traffic signs recognition based on cnn model for self-driving cars. In P. Vasant, I. Zelinka, and G.W. Weber, editors, *Intelligent Computing Optimization. ICO 2021*, volume 371 of *Lecture Notes in Networks and Systems*. Springer, 2022.
- [53] Shaoqing Ren, Ross Girshick, Ross Girshick, and Jian Sun. Faster r-cnn: Towards real-time object detection with region proposal networks. *IEEE Transactions on Pattern Analysis & Machine Intelligence*, 39(6):1137–1149, 2017.
- [54] Jifeng Dai, Yi Li, Kaiming He, and Jian Sun. R-fcn: Object detection via region-based fully convolutional networks. In *Proceedings of the Neural Information Processing Systems (NeurIPS)*, 2016.
- [55] G. Said. Efficient arabic handwritten character recognition based on machine learning and deep learning approaches. *Journal of Advanced Research in Dynamical & Control Systems*, 12(07-Special Issue):9–17, August 2020.
- [56] Hassina T., Said Gadri, Baya L., Nour El-Houda A., and Nadjat B. Handwritten digit recognition: Developing an efficient ml and dl model to recognize handwritten digits. In *Proceedings of CNIATI'21 Conference (Conférence Nationale sur l'Intelligence Artificielle et les Technologies de l'Information)*, University Chadli Ben Djedid, Al-Taref, May 2021.
- [57] J. Wang, Y. Gao, W. Liu, A. K. Sangaiah, and H.-J. Kim. Energy efficient routing algorithm with mobile sink support for wireless sensor networks. *Sensors*, 19(7):1494, 2019.

## Bibliography

---

- [58] S. Gadri, S. Chabira, S. Ould Mehieddine, and Kh. Herizi. Sentiment analysis: Developing an efficient model based on machine learning and deep learning approaches. In P. Vasant, I. Zelinka, and G.W. Weber, editors, *Intelligent Computing Optimization. ICO 2021*, volume 371 of *Lecture Notes in Networks and Systems*. Springer, 2022.
- [59] Z. Tang, X. Ding, Y. Zhong, L. Yang, and K. Li. A self-adaptive bell-lapadula model based on model training with historical access logs. *IEEE Transactions on Information Forensics & Security*, 13(8):2047–2061, Aug 2018.
- [60] Mohamed Zakaria Mekhalfia and Said Gadri. Drowsiness detection system: Developing an innovative model based on deep learning approach. In *1st International Workshop on Machine Learning and Deep Learning (WMLDL 2023)*, Faculty of Mathematics and Informatics, Mohamed Boudiaf University of M’sila, Algeria, March 07 2023.
- [61] Hasyiya Karimah Adli, Muhammad Akmal Remli, Khairul Nizar Syazwan Wan Salihin Wong, Nor Alina Ismail, Alfonso González-Briones, Juan Manuel Corchado, and Mohd Saberi Mohamad. Recent advancements and challenges of aiot application in smart agriculture: A review. *Sensors*, 23(7):3752, 2023.
- [62] Hassina Ait Issad, Rachida Aoudjit, and Joel J.P.C. Rodrigues. A comprehensive review of data mining techniques in smart agriculture. *Engineering in Agriculture, Environment and Food*, 12(4):511–525, 2019.
- [63] Mathushika Vinushayini Gomes. *Smart Farming: Using Artificial Intelligence, Internet of Things, and Robotics - A Comprehensive Review*, chapter 1, pages 1–20. Taylor & Francis, 2021.
- [64] Judy Mathushika, Ravichandran Vinushayini, and Chandima Gomes. Smart farming using artificial intelligence, the internet of things, and robotics: A comprehensive review. *Journal Name*, Volume(Issue):Page Range, 2022.
- [65] Rosemary J. Thomas, Gregory O’Hare, and David Coyle. Understanding technology acceptance in smart agriculture: A systematic review of empirical research in crop production. *Technological Forecasting and Social Change*, 189:122374, 2023.