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**Computer Science Engineer Diploma**

**Master Degree In Intelligent Systems**

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# Implementation and Development of a Multi-sensor Mobile Vision System (2D Color, 3D, IR)

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# Appreciations & Signatures

**National School of Computer Science**

**Vilmorin Mikado**

*The work of Chayma MOUSSA was a real research and development work, her subject combined tests of android vision system but also image fusion and machine learning techniques. Chayma's report is quite well structured, Chayma has done a good job of highlighting her algorithmic work. The results part also has the merit to be underlined. simple and easy with metrics quite well chosen. Clear and well-structured this report will be a base for the team on the subject of mobile vision image fusion and related machine learning.*

## Abstract

In the world of computer vision, phenotyping under uncontrolled conditions is a challenging task as the images have complicated characteristics. The main purpose of this project is to study the feasibility of merging multi-sensor images (2D color, 3D, IR) and automate monitoring vegetable aspects remotely by Limagrain experts.



**Keywords: Computer Vision, Deep learning, Image Preprocessing**



## Résumé

Dans le monde de la vision assistée par ordinateur, le phénotypage dans des conditions non contrôlées est une tâche difficile car les images ont des caractéristiques compliquées. L'objectif principal de ce projet est d'étudier la faisabilité de fusionner des images multi-capteurs (2D couleur, 3D, IR) et d'automatiser le suivi des aspects légumes à distance par les experts Limagrain.



**Mots clés: Vision assistée par ordinateur, Apprentissage profond, prétraitement d'images**



## الملخص

في عالم رؤية الكمبيوتر ، يعد التنميط الظاهري في ظل ظروف غير منضبطة مهمة صعبة لأن الصور لها خصائص معقدة. الغرض الرئيسي من هذا المشروع هو دراسة جدوى دمج الصور متعددة المستشعرات (ثنائية الأبعاد ، ثلاثية الأبعاد ، الأشعة تحت الحمراء) وأتمتة مراقبة الخضار عن بعد بواسطة خبراء ليماغرين.



**كلمات مفاتيح: رؤية الكمبيوتر ، التعلم العميق ، المعالجة المسبقة للصور**

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# Acronyms

| | |
|---|---|
| **2D** | Two Dimensions |
| **3D** | Three Dimensions |
| **BBox** | Bounding Boxes |
| **CNN:** | Convolutional Neural Network |
| **FP** | False Positive |
| **FCNN:** | Fully Connected Neural Network |
| **GAN:** | Generative Adversarial Network |
| **GPU** | Graphical Processing Units |
| **HOG** | Histograms of Orientated Gradients |
| **IR:** | InfraRed |
| **mAP:** | Mean average Precision |
| **PCL** | Point Cloud Library |
| **PSNR:** | Peak Signal-to-Noise Ratio |
| **R&D:** | Research and Development |
| **RGB:** | Red, Green, Blue |
| **RPN** | Region Proposal Network |
| **SIFT** | Scale-Invariant Feature Transform |
| **SRGAN:** | Super-Resolution Generative Adversarial Network |
| **SSIM:** | Structural Similarity Index Measure |
| **SVM** | Support Vector Machine |
| **TP** | True Positive |

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# General Introduction

Recent trends in population expansion have come about in augmented demand for agricultural products, resulting in an explosive influence on the agriculture industry development. To satisfy the demand, automation is utilized to boost production and quality. Automation in agriculture is comparatively challenging to industrial automation due to the field conditions and outdoor environments. The agriculture sector brings specifications in the systems which can be capable of controlling the growth of the fruits with a high-level accuracy.

For such systems, correct detection and classification are a crucial factor for agriculture control. Generally, fruit characteristics have been playing a noteworthy role and very critical aspects for the growth of the economy in agri-Food industries. The hosting company, Vilmorin-Mikado, employs yearly around 30% of its member-staff working under research and development in order to increase their product quality. Each year new typologies, new varieties of fruits are studied and examined by research and development team.

Among the planted fruits some are off-types; some have different volume than its neighbors, some have different color than its neighbors etc. These off-types should be removed as it causes losing money due to non-consumed lettuce. Moreover, the preservation of these fruits will harm the market of the company brand-name. However, experts can not visit the fields that are in several countries to check off the off-types in each area because it is a waste of time, energy and money.

In order to monitor the fruits, some images should be sent to the experts. However due to the fact that images some are taken under uncontrolled conditions, images are blurry sometimes, sometimes too dark or too light. For these reasons, experts should receive images with good quality, where the fruit is too clear.

With the aim to solve these problems, Limagrain is looking to automate this task by combining the three image sources(2D color, 3D, Infrared) aiming to have a good quality image, then to introduce an algorithm that can classify lettuce to normal and abnormal and then detect the off-types.

In this document, we will explain the process behind the work done. We split it into 5 main chapters that represent the most considerable phases of the project.

The first chapter presents the general context of the project. In this chapter, we start by citing the host organization, then we describe the project by detailing its academic context and objectives, the plant phenotyping concept and the problem statement. We conclude the chapter by explaining the project management approach.

The second chapter represents the preliminary study of the different concepts of computer vision and image processing. Then we detail the basics of Deep Learning in image processing.

The third chapter represents the start of the research phase and contains the literature review and an analysis of the state of the art. Since this project deals with different but interconnecting components, each part was reviewed separately like Multi sensor Image Fusion and the object detection and classification.

The fourth chapter explains the data acquisition and preparation phase. We start by describing the required data and the used tools for the data acquisition. We end with presenting the data processing and preparation process. Finally, we describe the obtained data sets.

The fifth and last chapter signals the start of the modeling phase where we present the proposed models. Then, we present the design of the software and the technologies that were exploited. Later, we present in detail the evaluation metrics used. Finally, we represent the obtained results and analyze in detail their interpretation and extract from them the best solutions.

We end the report by resuming the context of the project and the process of work done. Then, we cite the highlights that can extend and enhance the project in the future.

# Chapter 1

# General Context

This chapter is a very elaborated overview of end-of-studies project. It is divided into three parts: In the first one, we present our host company and its major activities. In the second part, we introduce the project context as well as the problem description. In the third part, we give an idea the project management approach that enabled us to achieve the work successfully.

## 1.1 Hosting Company

Vilmorin Cie was established on a history that spans over 280 years. In 1743, Pierre Andrieux founded the first store at Quai de la Megisserie in Paris by , Louis XV's seed trader and his wife. Their daughter Adelaide d'Andrieux married to Philippe-Victorie De Vilmorin and renamed it "Vilmorin-Andrieux" in 1774. Till today, the home office of Vilmorin Cie is at the above address.

In 1993, Vilmorin Cie was registered on the Paris stock exchange. The Limagrain's Field Seeds are integrated within the scope of Vilmorin Cie in 2006 and 2007. After that, there has constantly been a boost in the growth and globalization. As a seed firm, Vilmorin Cie is mainly centered on the agricultural field [N2]. Agriculture confronts various problems, the foremost exigent of which is providing the worldwide food needs with regards to both health and volume. Seeds are a concentrated source of solving that can help fix these problems. With respect to research spending, the seed business is one of the foremost demanding.

In 1975, Group Limagrain bought Vilmorin Cie and by 1989 it specialized in vegetables, flowers, and tree seeds for private persons and garden items, most notably with its Oxadis brand, which is now Vilmorin Jardin. Limagrain, an international agricultural co-operative organization founded by farmers in 1965, focuses its activity on three key fields: vegetable seeds, field seeds, and cereal goods. Crop production, field seeds, vegetable seeds, garden goods, baking and pastry goods, and cereal ingredients are among the 14 Business Units (BU) that make up the organization. The Limagrain Agro-Production BU is in charge of seed production, cereal and vine gathering, storage and processing, as well as agri-supplies, animal feed and garden goods for farmers.

Vilmorin-Mikado is stationed in La Menitre, Maine-Et-Loire. The 8-hectare site houses a firm and a research center employing 400 workers . The R&D laboratory Techno-Seeds and Artificial Vision, headed by Mr. Pierre FERRATON, carries out experimental studies on a variety of challenges attempted at enhancing seed quality. The Techno-Seeds hub concentrated in chemistry, physiology, disinfection, and seed treatment. The Artificial Vision group is working on image processing and automation. The Artificial Vision department is splited into two teams: Artificial Vision and Automation, with Mrs. Cindy TORRES and Mr. Ali BOUDJEDRA serving as project managers for each. Mr. Oliver ROBERT- Artificial Vision Engineer and Mr. Cyril DAMBRINE- Artificial Vision and Automation engineer, are both on the team.
The figure 1.1 illustrates the logo of the company.

Figure 1.1: Vilmorin Mikado Logo

## 1.2 Project Description

### 1.2.1 Academic Context

This project is a part of a 6 month end-of-studies internship required for the obtaining of the diploma of engineer in computer science from the National School of Computer Science of Tunisia. This project serves also for the master's degree in Intelligent Systems. The internship took place in Vilmorin Mikado's Computer Vision Research and Development Laboratory between March $15^{th}$, and August $31^{th}$, 2021.

### 1.2.2 Plant Phenotyping

Phenotyping is the basis of every breeding selection approach. Modern plant phenotyping assess composite features connected to physiology,growth, yield, development, resistance and stress adaption with greater accuracy and precision at the diverse scale of organization, from organs to canopies[N3].According to a more modern and full definition, Plant phenotyping is the evaluation of complex plant characteristics like tolerance, growth, ecology, and the basis measurement of individual quantitative parameters that offer the foundation for complex trait evaluation[N4].

Phenotyping is also a research method that consists in documenting quantitative and qualitative plant features in order to identify whether to breed for new cultivars, regulate or improve plant production processes. It is conceivable to boost agricultural productivity to serve the requirements of the expanding human population by extracting and quantifying plant features and establishing the connection between genotype and phenotype [N5].

Identifying the origin and characteristics of a plant needs many phases, such as data acquisition (2D/3D, spectral), detection and extraction of the object from the background, removal of occlusions, use of non-standard imaging, and handling serious diseases and pathogens that are frequently hardly visible. Since the phenotyping process takes many years and that the plant's variability generated this year will differ from the previous year, makes it challenging. Some characteristics require the skills of a highly seasoned professional. Consequently, the work of developing a digital phenotyping system is analogous to the modeling of human knowledge.

### 1.2.3 Problem Statement

In this multidisciplinary master thesis, we try to use artificial intelligence techniques to solve a novel challenge in the phenotyping field of research, using lettuce as a case study. The goal of this thesis is to investigate the viability of utilizing state-of-the-art artificial intelligence methods in phenotyping tasks, by evaluating various datasets which provide the fruits characteristic's traits under uncontrolled conditions.

Having a world production greater than 24.9 million tons , a value which continues to increase every year, lettuce has always been one of the world's major consumed vegetables. Lettuce production has been subsequently gaining interest as it is used in dishes in different parts of the world: salads, soups, wraps, sandwiches, ...

The Limagrain plants a large variety of vegetables such as lettuce and cauliflower. For lettuce, Limagrain plants between 250 and 300 varieties. The most planted typologies are Romaine, Multi-leaf, Batavia, Chene, Iceberg, Beurre. Lettuce, depending on the typology, has different characteristics for the volume, color, foliage and shape of the leaves. They are planted in the greenhouse tunnels of Limagrain and after 4 weeks they are transferred and planted at its producers in different countries around the world.

As far as the commercial fact is concerned, when lettuce will be extracted, some have off-types. For lettuce, some have different colours from other lettuces of the same variety, some have a different volume, some have a different shape of leaves and some have no center as illustrated in the figure 1.2. These must be abandoned because it causes losing money due to non-consumed lettuce. Moreover, the preservation of these lettuces will harm the market of the brand-name limagrain. Limagrain experts can not, also, visit the fields that are in several countries to check off the off-types in each area because it is a waste of time, energy and money.


Figure 1.2: Lettuce Off-types

Generally, lettuces are planted in greenhouse tunnels belonging to the producers of Limagrain. The interior of a greenhouse tunnel is a challenging environment because the lighting conditions vary a lot. Most color sensors do not work reliably under all these conditions. For example, color sensors are ineffective under low-light conditions at night, while infrared cameras are ineffective under direct bright sunlight.

Aiming to fix this problem, experts asked producers to send pictures of lettuce planted in greenhouses, outdoors and indoors, but since lighting conditions are not always good, they could not detect off-types; images are blurry sometimes, sometimes too dark or too light. Producers should therefore send pictures, of good quality, where the lettuce is too clear, taken in various and uncontrolled conditions.

In order to solve all of these problems, Limagrain is looking to automate this task by combining the three image sources(2D color, 3D, Infrared) aiming to have a good quality image, then to introduce an algorithm that can classify lettuce to normal and abnormal and then detect the off-types.

### 1.2.4 Objectives

As tasks to be accomplished to fulfill the primary goal, the objectives are listed below:

- Research on the edge-cutting state of the art techniques in computer vision for image fusion (2D color, 3D, Infrared), classification, detection for use in plant phenotyping tasks.
- Data acquisition in the fields of the Limagrain producers.
- Model training and experimenting on different networks for fusion images.
- Creation of data pipelines for the different labeled data sets for model training.
- Model training and experimenting for classification on different datasets.
- Model Deployment of the model into edge devices for instance results.

## 1.3 Project Management Approach

The work approach plays a major role in project realization and success. That's why we have to choose a methodology that responds to the project requirement and makes the work process more efficient. Considering the nature of our project which is based on artificial intelligence and involves business understanding, data preparation, modeling, evaluation, and finally the deployment we choose the agile approach Cross-industry standard process for data mining( CRISP-DM) that suits very well the requirement of our project.

### 1.3.1 CRISP Methodology Description

The CRISP method (originally called CRISP-DM) was originally developed by IBM in the 1960s to run data mining projects. The CRISP method is divided into 6 stages, from understanding the business challenges to deployment.

#### 1.3.1.1 Understanding the Business Problem

The first step is to understand the business elements and problems that artificial intelligence aims to solve or improve. In our project, we focused on understanding the problems with the traditional bylaws document processing, as well as how we may apply AI techniques to automate that task.

#### 1.3.1.2 Understanding the Data

The aim of this step is to precisely specify the data that we need, and we analyze the quality of the existing data to identify the main information that must be retrieved in order to offer the required solution.

#### 1.3.1.3 Data Preparation

This step includes activities related to the construction of a set of the required data to be analyzed. It, therefore, includes the documents file processing and format transformation as well as text labeling. In order to have data prepared and compatible with the algorithms to be used.

#### 1.3.1.4 Modeling

Modeling includes the choice, the parametrization and the testing of various algorithms as well as their sequence, which constitutes a model.

#### 1.3.1.5 Evaluation

The goal is to validate the models and algorithms used, as well as the knowledge acquired, using various metrics such as precision, recall, and F1 score to ensure that they meet the objectives. It also helps through analyzing the results, determining what improvements can be made to achieve better results the next time.

#### 1.3.1.6 Deployment

This is the last step in the process. It includes putting the resulting model into production for the end user. Its objective is to place the knowledge acquired through modeling in an appropriate form and to integrate it into the decision-making process.
Figure 1.3 shows the general CRISP-DM project life cycle starting from business understating to the deployment.

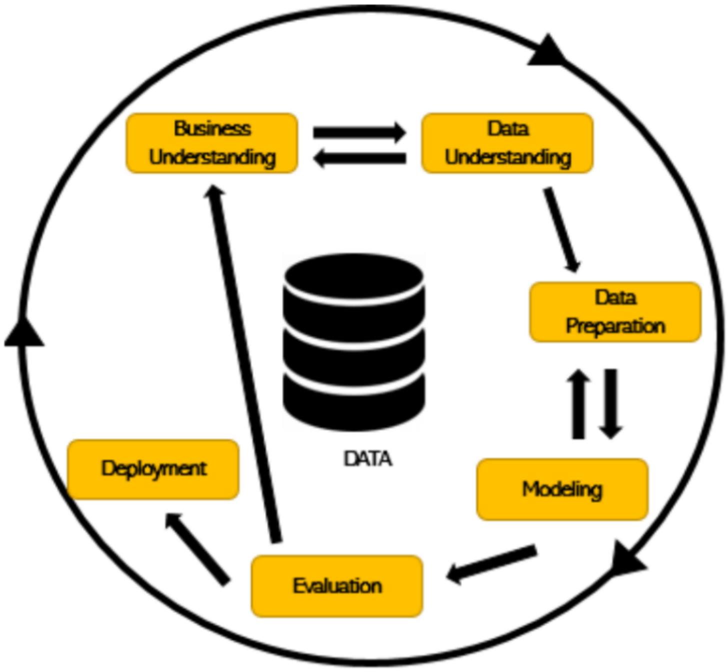


Figure 1.3: CRISP DM Project Life Cycle

## 1.4 Conclusion

In this chapter we presented the host company and its activities, highlighted the context of our project, describing the problem statement and the objectives. This chapter also presented the project management approach which is CRISP-DM detailing the project life cycle. The next chapter is devoted for the theoretical study of the state-of-the art by introducing some basic concepts to understand the current issue.