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An IoT Architecture as a means of Optimizing Downy and Powdery Mildew Diseases Recognition in Portuguese Vineyards

Bruno Pedrosa Gomes

Dissertation Proposal report presented as partial requirement for obtaining the master's degree in Information Management

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AN IOT AND AI ARCHITECTURE AS A MEANS OF OPTIMIZING DOWNY AND POWDERY MILDEW DISEASES RECOGNITION IN PORTUGUESE VINEYARDS

by

Bruno Pedrosa Gomes

Dissertation Proposal presented as partial requirement for obtaining the master's degree in Information Management, with a specialization in Information Technology System Management

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ABSTRACT

The agriculture is a livelihood of an expressively number of people and companies in Portugal, and before covid time surpassed 1.000 Million EUR, so it is an important portion and should be, at least, maintained.

A part of this agricultural production is destinated to produce wine, that itself a part of the Portuguese culture, and to help the vineyards health increase this work aims to understand the grape-fruit diseases, his types, and mainly how can be detected as early as possible. A reliable way to disease detection can facilitate treatment and possible cure of the vine, through proper management strategies and can improve productivity.

This research aims to propose a new architecture thar can provides a better solution for this disease identification. The proposed architecture is supported on the Internet of Things sensors technologies, that works 24/7 and, nowadays, are not expensive and bring another protection to the vineyards.

KEYWORDS

Internet Of Things; Vineyards; IT Architectures; Disease Recognition; IoT Devices

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LIST OF ABBREVIATIONS AND ACRONYMS

AI	Artificial Intelligence
CNVV	Catálogo Nacional de Variedades de Videira
DSR	Design Service Research
GDP	Gross Domestic Product
IPM	Integrated Pest Management
IoT	Internet of Things
IS	Information Systems
MS	Microsoft

1. INTRODUCTION

1.1 CONTEXT

Portugal is a country with 40.39% of territory reserved for agriculture activities according with the Trading Economics ("Portugal Agricultural Land Percent Of Land Area", 2019), and a method to at least maintain this crops+, is a good way to prevent any decrease in this production, but can also improve this one.

Agriculture in Portugal is a 832.70 EUR Million market, in the fourth quarter of 2018, as it can be seen this very recently data show how important is this sector. Agriculture GDP in Portugal averaged 822.82 EUR Million from 1995 until 2018 ("Statistics Portugal - Web Portal", 2019).

With the Portuguese production of grapes to do wines increased 11.29% between 2016 and 2017, that represents 800,738 and 896,089 crops ("Portugal GDP From Agriculture | 2019 | Data", 2019), but in 2018 Vineyards presented a considerable decrease, with 700,000 crops made. The vineyards representing, 12.09% of total crops in all types of agricultural products.

1.2 MOTIVATION

In the last year was the lowest wine production in the last two decades, because the resultants weak pollination, phytosanitary problems and the big heat wave in last August. In the specific case of vineyards, the problems extension was quite big, and almost all vineyards regions was affected causing this reduction crops, that was 2 million of hectoliters ("Statistics Portugal - Web Portal", 2019).

Because of this system that can help the predictive analyses of this phytosanitary problems probably will increase the harvest and quality of grapes.

In Portugal exists, approximately, two thousand wine productors, each of them can really appreciate if a system could identify any threat of production of them. In addition to that this system can really help the country amounts of money exporting to the international wine market. The opinion of some of the most important producers are that this system can help them not only in the early identification of diseases and treat the vineyards but also can improve the understanding about this plantation and help to improve which kind of interactions between the needs of the field and what the producers give them to grow. This study can also extend the knowledge of the oldest way to produce food, agriculture. How was presented, this study has a practical application.

1.3 STUDY OBJECTIVES

The main objective of this work is to propose an Internet of Things Information System Architecture for the early detection of diseases in vineyards using sensors, to detect and identify the diseases as soon as possible.

But there are some others intermediate objectives which are so important as the big one, as follow:

1. To study grapes varieties in Portugal;

2. To study the most common vineyard diseases and his types;
3. To study how these diseases can be detected;
4. To study the most IoT devices;

The first step is research grapes varieties. The second, the type of diseases in Vineyards, the most common diseases in Portuguese agriculture and group these diseases in types. The third is to study how these diseases can be detected, example examination the leaf of vines. The fourth phase of this research is to identify which are the best IoT sensor match with the type of detection of these types' diseases, including image processor using AI methods to recognition. And the last part will be Proposal n architecture to build a project to early detect diseases in Vineyards that can be applied in Portugal to improve the harvest and help. Agricultural economy to grow.

1.4 DOCUMENT ORGANIZATION

In the session 2 of this work, it can be found a synthesis about viticulture in Portugal, recently agricultural production, and relevant numbers, also a detailed catalog of grapes varieties in Portugal grouped by viticulture Portuguese regions. Then a list of the most common grape diseases classified per type. Last but not least an overview about state of the art of Internet of Things.

In the session 3 of this thesis, is explained the methodology applied and how it works. In fourth session is the Internet of Things Information System Architecture as a way to early detect the chosen diseases and which aspects and symptoms can be detected by the chosen sensors. And finally, the conclusion of the dissertation.

2. LITERATURE REVIEW

That recent data of crops show that the environment of agriculture is very instable and needs attention to avoid this phytosanitary problem in the future. As was shown in the previous paragraph, this slice of the sector is a multi-millionaire market and wine is a important national product for exportation. It will be important to mitigate the risk of vineyards diseases and his early identification to solve them faster, increasing the chance of goods harvest and qualities of the grapes, and because of that increasing the incomes and generate richness for the country.

2.1 VINICULTURE IN PORTUGAL

Portugal is a country with 40.39 % of territory reserved for agriculture activities (Trading Economics - "Portugal GDP From Agriculture | 1995-2020 Data | 2021-2023 Forecast | Historical" 2021)

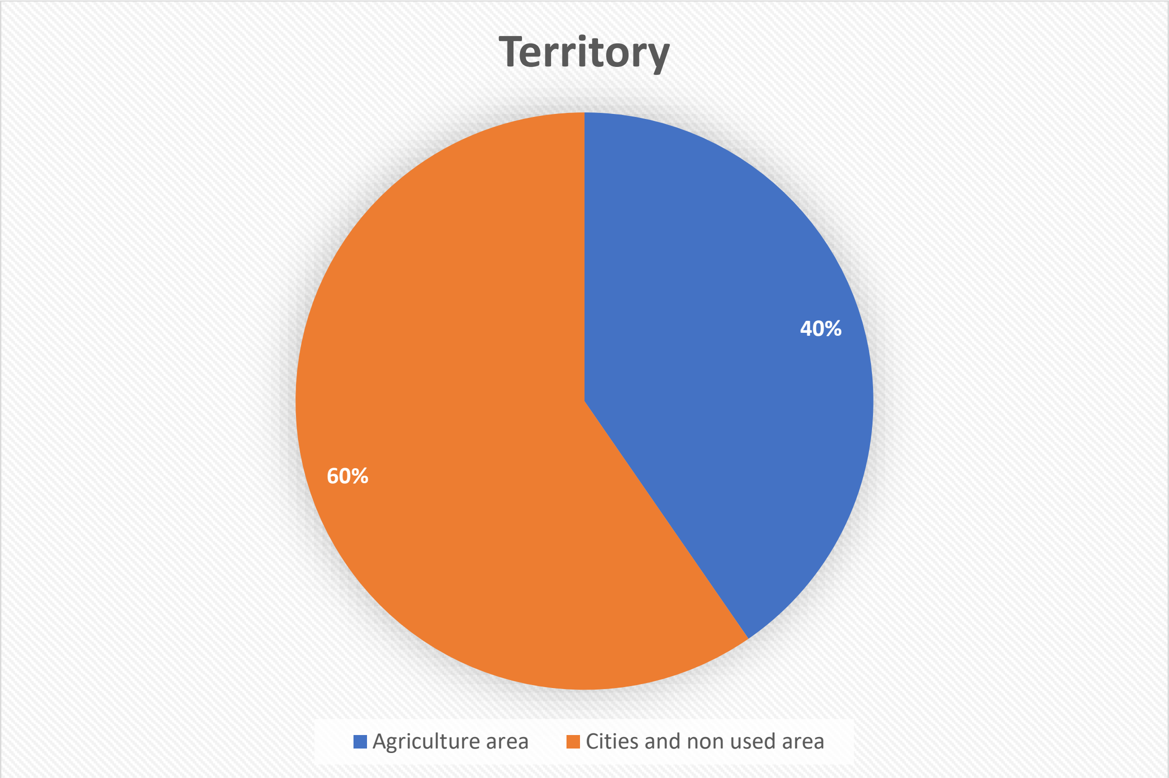

Figure 1 - Territory of Portugal by Agriculture Field and Cities

In addiction to that, the Gross Domestic Product (GDP) from Agriculture in the last 10 years, show incredible results.

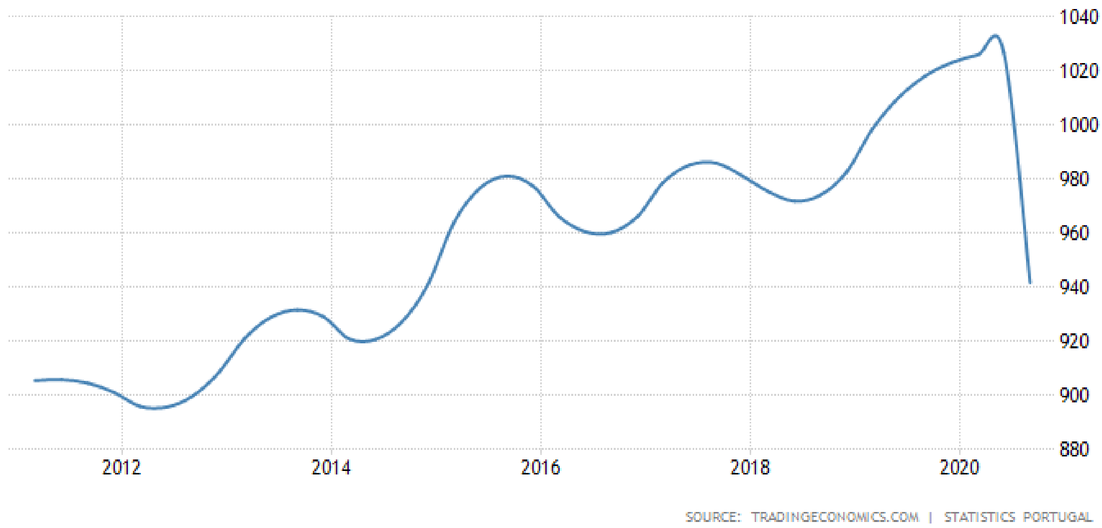

Figure 2 - Last decade agriculture GDP (Source:Trading Economics - "Portugal GDP From Agriculture | 1995-2020 Data | 2021-2023 Forecast | Historical" 2021))

GDP from Agriculture have been increasing since the 2008 crisis, with an ascendent curve, beating 1026.80 EUR Million in the first quarter of 2020. After that the COVID-19 pandemic area, reduced to 941.50 EUR Million in the second quarter of 2020 as it can be seen in Figure 3.

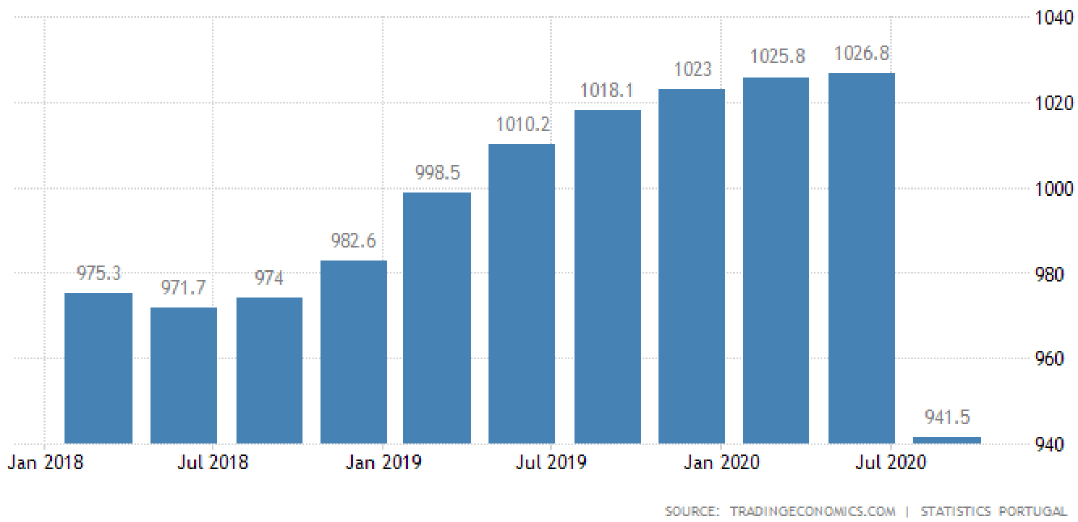

Figure 3 - Last 3 years Agriculture GDP (Source: ("Portugal GDP From Agriculture | 1995-2020 Data | 2021-2023 Forecast | Historical" 2021))

2.1.1. **Problem Identification**

"Pests and diseases of agricultural crops are as old as agriculture itself"(Russel, 1978, p. 3), and this idea comes with how the human beings can protect their fields and their plantation from those diseases. The diseases always existed, a virus can mutate quickly in the other hand a bacterium may exist from centuries until now being almost the same, so why some devastation can occur so fast like a overnight? A mainly definition how the ecosystems works itself is that how bigger the diversity is, more stable it be. "The greater the number of plants and animals that occupy an ecosystem, the greater are the checks and balances that prevent any one species from increasing to the point where other ecosystem components are threatened."(Ciesla, 2001, p. 4).

Sometimes may not be possible to avoid these pathogens and keep the danger away, in that cases the fast and correct detection of diseases can save the season crop. Taking advantage of advances in the field of technology, it is possible to aims to improve control over the areas for planting crops, and the use of this technology is what this study is about.

In the context of Portugal, as it is a country with a very present wine culture, and obviously grape plantations are at the base of this subject, diseases and pests in viticulture will be addressed, avoiding thus the food and economic loss of this crucial activity for this country.

2.1.2. **Grapes Varieties in Portugal**

Portugal is one of the most important country about *castas*, the grapes varieties, they are in a large number, so is right to say that Portugal has a casta heritage. In the *Catálogo Nacional de Variedades de Videira*, Vine Varieties National Catalogue (IVV, 2018)has exactly 269 different vine varieties, according to the *Instituto da Vinha e do Vinho* (IVV), the institute of vineyard and wine of Portugal, as it can be shown in the follow table:

Table 1 All Varieties permitted in Portugal (Source: Ministério da Agricultura, DGAV - Direção-Geral de Alimentação e Veterinária)

Varyeties' Name	Color	Other Name
Agronómica T	White	
Água Santa T	White	
Alfrocheiro T	Red	«Tinta Bastardinha (PT)»
Alicante Bouschet T	Red	
Alicante Branco B	White	
Almafra B	White	
Almenhaca B	White	
Alvadurão B	White	
Alvar B	White	
Alvar Roxo R	R	
Alvarelhão T	Red	«Brancelho (PT)»; «Brancellao (ES)»
Alvarelhão Ceitão T	Red	
Alvarinho B	White	«Albariño (ES)»
Alvarinho Lilás B	White	

Amaral T	Red	
Amor-Não-Me-Deixes T	Red	
Amostrinha T	Red	
Antão Vaz B	White	
Aragonez T	Red	«Tempranillo (ES)»;, «Tinta Roriz (PT)»
Arinto B	White	«Pedernã (PT)»
Arinto do Interior B	White	
Arinto dos Açores B	White	«Terrantez da Terceira (PT)»
Arinto Roxo R	R	
Arjunção T	Red	
Avesso B	White	
Azal B	White	
Baga T	Red	
Barcelo B	White	
Barreto T	Red	
Bastardo T	Red	«Graciosa (PT)»
Bastardo Branco B	White	
Bastardo Roxo R	R	
Batoca B	White	«Alvaraça (PT)»
Beba B	White	
Bical B	White	«Borrado das Moscas (PT)»
Boal Branco B	White	
Boal Espinho B	White	
Bonvedro T	Red	
Borraçal T	Red	
Branca de Anadia B	White	
Branco Desconhecido B	White	
Branco Especial B	White	
Branco Gouvães B	White	«Alvarelhão Branco (PT)»
Branco Guimarães B	White	
Branco Valente B	White	
Branda B	White	
Branjo T	Red	
Cabinda T	Red	
Caínho B	White	
Calrão T	Red	
Camarate T	Red	
Campanário T	Red	
Caracol B	White	
Caramela B	White	
Carrasquenho T	Red	
Carrega Branco B	White	
Carrega Burros T	Red	
Cascal B	White	

Casculho T	Red	
Castália B	White	
Castelã T	Red	
Castelão T	Red	«João de Santarém (PT)»; «Periquita (PT)»
Castelão Branco B	White	
Castelino T	Red	
Castelo Branco B	White	
Casteloa T	Red	
Cerceal Branco B	White	
Cercial B	White	«Cercial da Bairrada (PT)»
Chasselas Salsa B	White	«Chasselas Cioutat (FR)»
Cidadelhe T	Red	
Cidreiro T	Red	
Códega-do-Larinho B	White	
Colombard B	White	«Semilão (PT)»
Complexa T	Red	
Concieira T	Red	
Coração de Galo T	Red	
Cornifesto T	Red	
Corropio T	Red	
Corvo T	Red	
Crato Espanhol B	White	
Dedo de Dama B	White	
Defensor B	White	
Deliciosa T	Red	
Diagalves B	White	
Doçal T	Red	
Doce T	Red	
Dona Ana B	White	
Dona Joaquina B	White	
Dona Maria B	White	
Donzelinho Branco B	White	
Donzelinho Roxo R	R	
Donzelinho Tinto T	Red	
Dorinto B	White	«Arinto do Douro (PT)»
Douradinha B	White	
Encruzado B	White	
Engomada T	Red	
Esgana Cão Tinto T	Red	
Esganinho B	White	
Esganoso B	White	
Espadeiro T	Red	
Espadeiro Mole T	Red	
Estreito Macio B	White	
Fepiro T	Red	

Fernão Pires B	White	«Maria Gomes (PT)»
Fernão Pires Rosado R	R	
Ferral T	Red	
Folgasão B	White	
Folgasão Roxo R	R	
Folha de Figueira B	White	«Dona Branca (PT)»
Fonte Cal B	White	
Galego T	Red	
Galego Dourado B	White	
Generosa B	White	
Gonçalo Pires T	Red	
Gouveio B	White	«Godello (ES)»
Gouveio Estimado B	White	
Gouveio Preto T	Red	
Gouveio Real B	White	
Gouveio Roxo R	R	
Grangeal T	Red	
Granho B	White	
Jaen T	Red	«Mencia (ES)»
Jampal B	White	
Labrusco T	Red	
Lameiro B	White	
Larião B	White	
Leira B	White	
Listrão B	White	
Loureiro B	White	
Lourela T	Red	
Lusitano T	Red	
Luzidio B	White	
Malandra T	Red	
Malvarisco T	Red	
Malvasia B	White	
Malvasia Babosa B	White	
Malvasia Branca B	White	
Malvasia Cabral R	Red	
Malvasia Cândida B	White	«Malvasia di Lipari (IT)»
Malvasia Cândida Roxa R	Red	
Malvasia de São Jorge B	White	
Malvasia Fina B	White	«Bual (PT)», «Boal (PT)»;
Malvasia Fina Roxa R	Red	
Malvasia Parda B	White	«Farinheira (PT)»
Malvasia Preta T	Red	
Malvasia Preta Roxa R	Red	«Pinheira Roxa (PT)»

Malvasia Rei B	White	«Palomino (CY)»;«Listan B (FR)»;«Palomino Fino (ES)»;«Listán Blanco de Canarias (ES)»;
Malvoeira B	White	
Manteúdo B	White	
Manteúdo Preto T	Red	
Marquinhas B	White	
Marufo T	Red	«Mourisco Roxo (PT)»
Melhorio T	Red	
Melra T	Red	
Mindelo T	Red	
Monvedro T	Red	
Moreto T	Red	
Moscargo T	Red	
Moscatel de Alcobaça B	White	
Moscatel de Hamburgo T	Red	«Moscato d'Amburgo (IT)»; «Muscat de Hambourg N (FR)»; «Muškat Hamburg (SI)»
Moscatel Galego Branco B	White	«Muscat á Petits Grains B (FR)»
Moscatel Galego Roxo R	R	«Muscat á Petits Grains Rg (FR)»;«Moscatel Roxo (PT)»
Moscatel Galego Tinto T	Red	
Moscatel Graúdo B	White	«Moscatel de Setúbal (PT)»; «Muscat d'Alexandrie B (FR)»; «Damaszener Muskat (AT)»;; «Müscat of Alexandria (CY)»;; «Moscatel de Alejandria (ES)»;; «Moschato Alexandrias B (EL)»;; «Moscato di Alessandria (MT)»;
Moscatel Nunes B	White	
Mourisco T	Red	
Mourisco Branco B	White	
Mourisco de Semente T	Red	
Mourisco de Trevões T	Red	
Mulata T	Red	
Naia B	White	
Negra Mole T	Red	
Nevoeira T	Red	
Padeiro T	Red	
Parreira Matias T	Red	
Patorra T	Red	
Pé Comprido B	White	
Pedral T	Red	
Perrum B	White	
Pexém T	Red	
Pical T	Red	«Piquepoul Noir (FR)»
Pilongo T	Red	
Pintosa B	White	
Praça B	White	
Preto Cardana T	Red	

Preto Martinho T	Red	
Primavera T	Red	
Promissão B	White	
Rabigato B	White	
Rabigato Franco B	White	
Rabigato Moreno B	White	
Rabo de Anho T	Red	
Rabo de Lobo T	Red	
Rabo de Ovelha B	White	
Ramisco T	Red	
Ratinho B	White	
Ricoca T	Red	
Rio Grande B	White	
Roal R	R	
Rodo T	Red	
Roseira T	Red	
Roupeiro Branco B	White	
Roxo Flor R	R	
Roxo Rei R	R	
Rufete T	Red	«Tinta Pinheira (PT)»
Samarrinho B	White	«Budelho (PT)»
Santareno T	Red	
São Mamede B	White	
Sarigo B	White	
Seara Nova B	White	
Sercial B	White	«Esgana Cão (PT)»
Sercialinho B	White	
Sevilhão T	Red	
Sezão T	Red	
Síria B	White	«Roupeiro (PT)»;«Códega (PT)»
Tália B	White	«Ugni Blanc B (FR)»; «Trebbiano Toscano B (IT)»
Tamarez B	White	«Molinha (PT)»
Terrantez B	White	
Terrantez do Pico B	White	
Tinta Aguiar T	Red	
Tinta Aurélio T	Red	
Tinta Barroca T	Red	
Tinta Caiada T	Red	« Tinta Lameira (PT)»; «Pau Ferro (PT)»;
Tinta Carvalha T	Red	«Carcajolo N (FR)»
Tinta da Barca T	Red	
Tinta de Alcobaça T	Red	«Alcoa (PT)»
Tinta de Lisboa T	Red	«Bastardo Tinto (PT)»
Tinta Fontes T	Red	
Tinta Francisca T	Red	

Tinta Gorda T	Red	
Tinta Grossa T	Red	«Carrega Tinto (PT)»
Tinta Martins T	Red	
Tinta Mesquita T	Red	
Tinta Miúda T	Red	«Graciano (ES)»
Tinta Negra T	Red	«Molar (PT)»;«Morrastel (FR)»:«Saborinho (PT)»
Tinta Penajóia T	Red	
Tinta Pereira T	Red	
Tinta Pomar T	Red	
Tinta Tabuaço T	Red	
Tintem T	Red	
Tintinha T	Red	
Tinto Cão T	Red	
Tinto Pegões T	Red	
Touriga Fêmea T	Red	
Touriga Franca T	Red	
Touriga Nacional T	Red	
Trajadura B	White	«Treixadura (ES)»
Transâncora T	Red	
Trigueira R	R	
Trincadeira T	Red	«Trincadeira Preta (PT)»:«Tinta Amarela (PT)»;
Trincadeira Branca B	White	
Trincadeira das Pratas B	White	
Triunfo T	Red	
Uva Cão B	White	
Uva Cavaco B	White	
Valbom T	Red	
Valdosa T	Red	
Varejoa T	Red	
Vencedor B	White	
Verdelho B	White	
Verdelho Roxo R	R	
Verdelho Tinto T	Red	
Verdial Branco B	White	
Verdial Tinto T	Red	
Vinhão T	Red	«Sousão (PT)»
Viosinho B	White	
Vital B	White	
Xara T	Red	
Zé do Telheiro T	Red	
Total	**269**	

As it can be seen, the red wines are the majority when compared to the white and roses grape, 131 red vines, 121 white vines and 17 rose wines.

2.1.3. **Regions**

According to Wine Tourism Portugal Web Site, although shrouded in many doubts and myths, it is thought that the vine was first cultivated in the Tagus and Sado valleys, around 2000 BC, by the Tartessian.

Throughout the Phoenician era, around the 10th century BC, until the 7th century BC, when the Greeks settled in the Iberian Peninsula and developed viticulture, and then the Celts in the 6th century BC, with whom the vineyard was already familiar, brought for the Peninsula the varieties of vines they cultivated. In other words, the history of wines in Portugal is as old as the history of Portugal itself.

In a recent period of this history, in the 19th century, a dark season for viticulture set in the phylloxera plague, which first appeared in the Douro region around 1865, spread quickly all over the country, devastating almost all the wineries' regions.

In 1907/1908, the process of official regularization of several other appellations of Portuguese origin began. In addition to the region producing Port Wine and Douro table wines, other regions whose wines were already famous began to demarcate themselves: Madeira, Moscatel de Setúbal, Carcavelos, Dão, Colares and Vinho Verde.

Currently, 33 Denominations of Origin and 8 Geographical Indications are recognized and protected throughout the Portuguese territory.

All regions In Portugal produces grapes for wines, from north to south, from east to west, and each of them has an specific climate, humidity, temperature and solar exposition. The continental regions are Minho, Trás-os Montes, Douro e Porto, Terras de Cister, Beira, Atlântico, Terras da Beira, Terras do Dão, Tejo, Lisboa, Península de Setúbal, Alentejo and Algarve. And the islands regions are Azores and Madeira, as we can see in the image below.

Figure 4 – Map of types of grapevine per region in Portugal. (Source https://www.winesofportugal.com/us/travel-wine/wine-regions/)

2.1.4. **Vineyards Diseases and his Types**

As any other type of plant, the Vineyards can be sick, and these diseases are caused by some reasons. It can be a virus, a bacterium, some fungal can cause other disease or some pests can damage a vineyard. In this chapter the disease and his types will be detailed.

Accurate and fast identification those diseases in the vineyard is the main action that should be done, to prevent the risk of losses in yield and the quality of grapes. “The first step in an effective pest management program is correct identification of the disease” (Carisse, Bacon, Lasnier, & McFadden-Smith, 2016).

2.1.4.1. Fungal diseases

In viticultural environment the fungal diseases are known as rottenness, and they can cause decay of the fruit and/or of the leaves.

In Europe some fungal are no rare and are very known, as Downy Mildew (Plasmopara viticola), Powdery Mildew (Erysiphe necator), Gray Mold / Botrytis (Botrytis cinerea), Dead Arm, Black Rot, Phytoplasma (Doman, 2015). Is all about fungus but they differ to each other. In the next pages will be shown more details of those diseases.

Downy Mildew

Scientific Name: Plasmopara viticola

According to Integrated Pest Management (IPM) sector of Ontario Ministry of Agriculture (“Ontario Crop IPM,” n.d.), this disease can be identified analyzing the leaves, shoots, rachis and berries. In the leaves I can be found a roughly circular yellowish discolorations, called “oil spots”, a white fluffy growth primarily on the lower leaf surface, they can also turn brown from the center outward as lesions age, and they can drop when they are severally infected.

In the infected shoot can turn into tips curl (“shepherd’s crook”) and covered with white fluffy sporulation.

The rachis with severe infections will cause itself a twist like a corkscrew and the entire surface can be covered with sporulation.

In the berries, it can happen a white fluffy sporulation when shot size, it may shrivel and drop off, the berries infected when smaller size, 3 to 5 millimeters, will turn color prematurely, those of white cultivars acquire a mottled appearance and they stay hard when healthy berries start to soften at veraison.

The cycle of Downy Mildew starts from the end of the summer to autumn the Oospores are formed, from the mycelium inside the leaves, shoots or berries. During the autumn when the leaves and bunch parts fall, the Oospores goes with them and that infected part they hibernate and spread in the soil for 3-5 years (possibly up to 10 years) (Taylor, 2021).

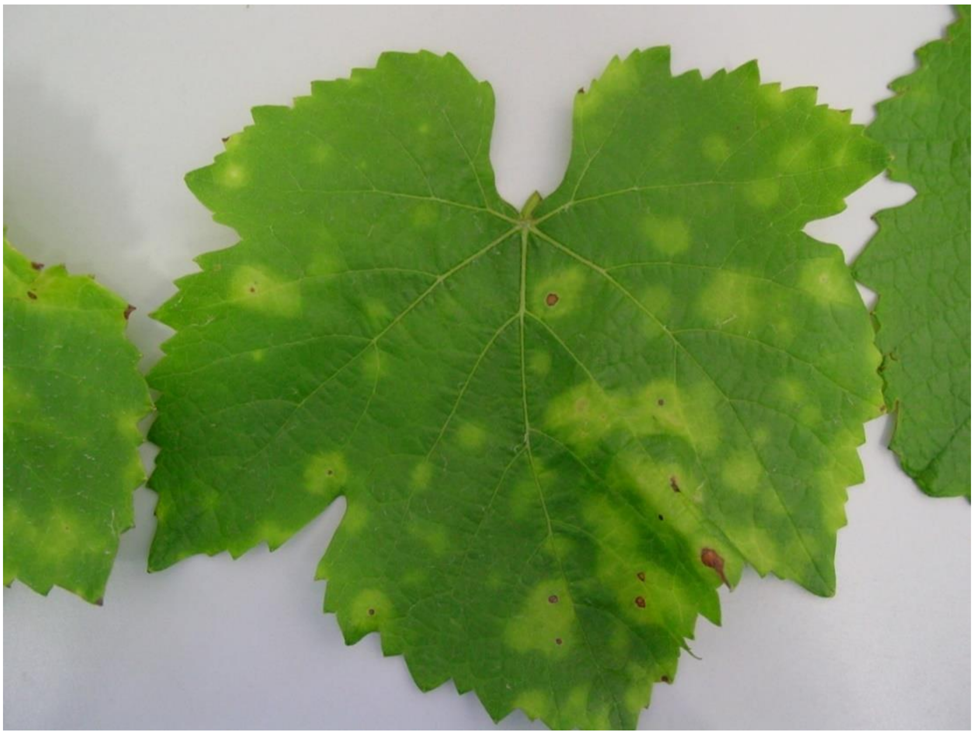

Figure 5 – Leaf of grapevine with Downy Mildew disease (Source: https://www.agric.wa.gov.au/table-grapes/downy-mildew-grapevines?page=0%2C1)

Figure 6 – Berries of grapevine sick by Downy mildew (Source: http://www.omafra.gov.on.ca/IPM/english/grapes/diseases-and-disorders/downy.html)

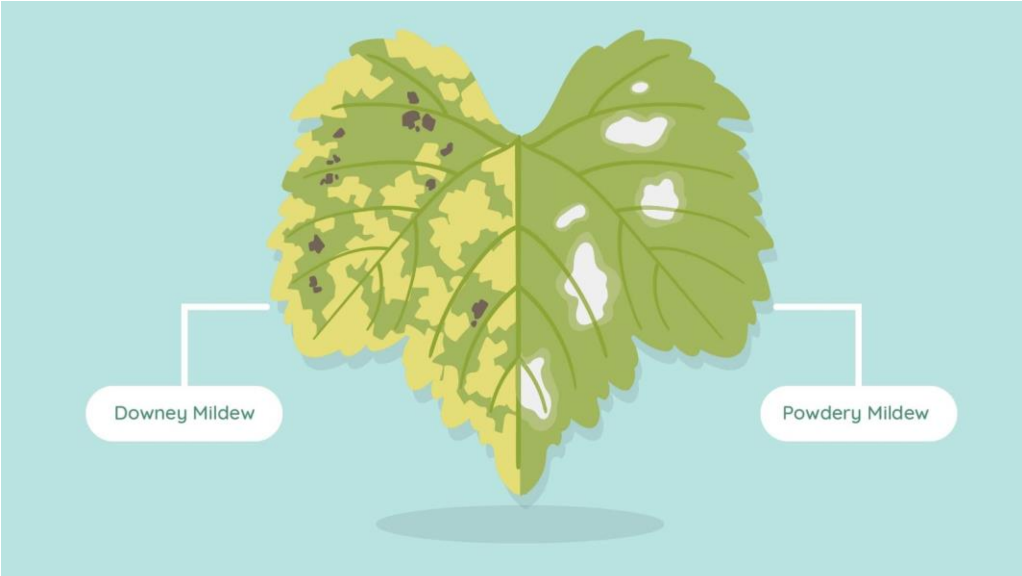

Figure 7 – Difference between Downey Mildew and Powdery Mildew. (Source: https://plantix.net/en/blog/controlling-downy-mildew)

Powdery Mildew

Scientific Name: Erysiphe necator (previously Uncinula necator)

The identification of powdery mildew turns easier when on all tissues, it looks like a greyish-white (“Ontario Crop - Integrated Pest Control,” n.d.)powder. In the leaves is frequently first found on the undersides, in the other hand on the upper sides of leaves the lesions become visible. In case of the disease is left unchecke, the number and size of leaves can increase. In a fast-growing leaf, infections on the underside may cause the leaves to appear puckered on top, in case of occur in infected leaves may become brittle and drop off.

On the shoots a greyish white, develop into brown irregular blotches, they grow up to a few centimeters and indistinct margins and remain visible after shoot hardening. The Rachis can become brittle and clusters can drop easily. The Berries can become covered by conidia, an initial floury can appear and in severe cases can become darker, the berries can dry and drop.

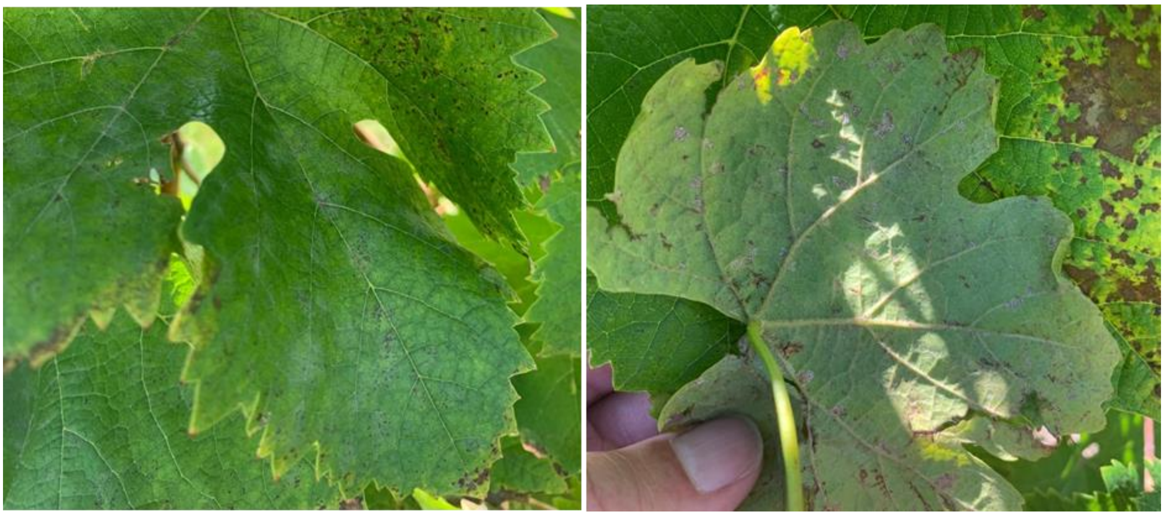

Figure 8 - Powdery mildew on the upper side of a grapevine leaf (left) and downy mildew spores on the underside of a leaf (right). Matt Clark, University of Minnesota. (Source: https://americanvineyardmagazine.com/post-harvest-disease-management-for-grapevine-downy-powdery-mildew/)

Gray Mold

The most common disease phase is the infection of ripe berries and also the most destructive, they become watery and soft. The white grape become shriveled and with a brown color, and the red ones develop a reddish color. Under high humidity weather, the berries usually become with a gray cover growth of fungus mycelium. Not all the berries are always infected, it can one, two, or the entire bunch. In general, when healthy berries touch the infected ones, they will become infected. In the leaf this infection begins as light green patches, commonly surrounded by a vein, this spots quickly turn into rotten tissue ("Ontario Crop - Integrated Pest Control," n.d.).

Figure 9 - Botrytis bunch rot of grape. (Source: https://ohioline.osu.edu/factsheet/plpath-fru-03)

Eutypa dieback (old Dead Arm Disease)

Scientific Name: Eutypa dieback (caused by Phomopsis viticola fungus, they are different diseases that may occur simultaneously)

The first symptom is the hardest to find because it is internal, covered by a bark. But generally, this type of canker generally, it forms around of a pruning wounds in older wood of the main trunk. Bellow the bark close to the canker shows a part of darkened or discolored wood, it can be found from a bark to the trunk´s center (Michael A. Ellis, 2008).

Figure 10 – Trunk infected byeutypa dieback

Black Rot

Scientific Name: Guignardia bidwellii

The Identification of Black Rot in leaves can be detected by a small lesion, until 10 millimeters, and light brown lesions surrounded by a darker area with a marginal ring of small black pycnidia. It also possible to identify Black Rot by berries, they can become light brown, after that to purplish brown than finally with black, they can become covered with black pycnidia, dry up to become mummified and finally most of the time will stay on the rachis. By shoots this disease can be identified too, under high disease pressure brown to black elongated lesions develop and pycnidia may appear (“Ontario Crop - Integrated Pest Control,” n.d.).

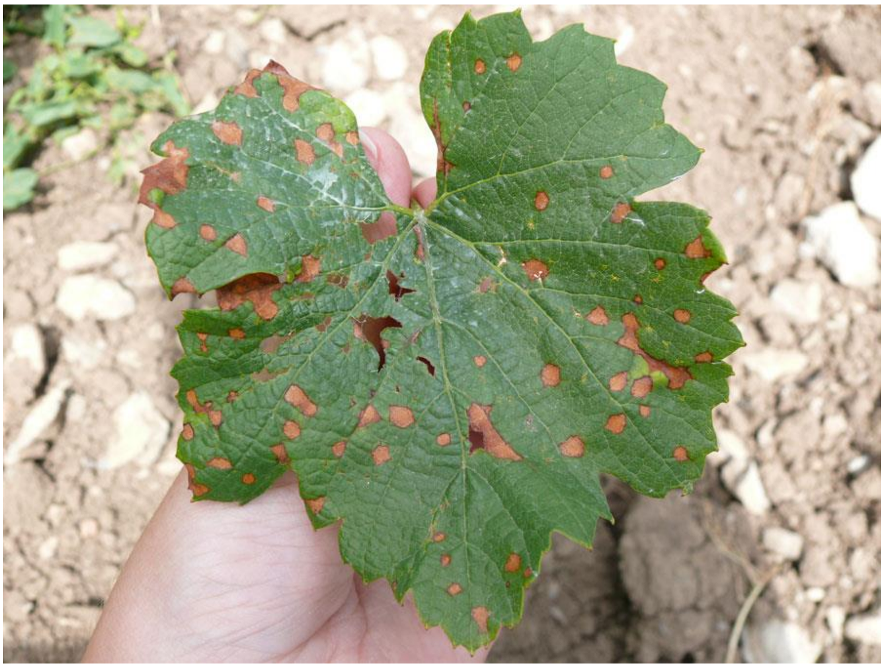

Figure 11 - Black Rot Leaf. Source (Ontario Grape IPM, 2021 - http://www.omafra.gov.on.ca/IPM/english/grapes/diseases-and-disorders/black-rot.html)

2.1.4.2. Virus and Virus like Diseases

Grape Feanleaf virus (GFLV)

Scientific Name: Grapevine fanleaf Virus Nepovirus(GFLV) / Arabis Mosaic Virus Nepovirus (ArMV)

The identification can be done analyzing the shoots, they can turn the internode shorter, zigzag growth, the nod can have many shoots. The variations in leaves are that they can be malformed with some anomalies, and they can have they can have a form like an open fan, the leaves margin is extremely anomalous, can a green and yellow mosaic pattern appear on leaves, yellow lines or ring format across the main veins, during the summer with warmer temperatures, the yellowing and flecking symptoms often disappear quickly.

As happen with leaves, the berries can be totally transformed and the berries set production can reduce up to 80% and clusters may abort with very small number of berries (“Ontario Crop - Integrated Pest Control,” n.d.).

Figure 12 - Veinbandding symptoms (Source: Courtesy of A.C. Goheen / http://www.omafra.gov.on.ca/IPM/english/grapes/diseases-and-disorders/fanleaf.html)

Grapevine Leafroll Disease

Scientific Name: Grapevine leafroll-associated (CLRaV) closteroviruses

In general, the infected vine, by leafroll virus, show less vitality, with small leaves and produce less yields compared to healthy vine. In addition, berries from sick vines show unequal maturity and fruit size, even zero produced sugar, and light and unhealth color. The difference size of red grapes is more notable when compared with the white ones ("Symptoms | WSU Viticulture and Enology | Washington State University," n.d.).

Figure 13 - Difference between a health and infected vine leaf (Source: https://wine.wsu.edu/extension/grapes-vineyards/grape-diseases/virus-diseases/symptoms)

Figure 14 – Red color leaf with mains veins still green (Source: http://www.omafra.gov.on.ca/IPM/english/grapes/diseases-and-disorders/leafroll.html)

Grapevine Red Blotch

Scientific Name: Grapevine red blotch, Geminiviridae

The leaf characteristics of a infected vine when compared with a health plant has no visible in the spring, so it´s can turn theirs recognition more difficult.. But in the middle to the end of the summer can red spots or blotches be starts appear, with the majority leaves becoming red. On red vines the shades of red may vary from crimson to purple color. On white ones, leaf symptoms are not very expressive and usually appear in non-regular chlorotic areas that can become necrotic in late autumn, older leaves at base of the canopy first affected and in the end of the season, the most symptomatic leaves often drop off earlier.

In the berries they usually have the same size then the healthy ones, but the cluster are smaller, with less berries, that may cause from 30 to 50 percent loss in yield, they often matures late and non-regular, and has up 50 percent decrease in sugar production and has poor pigmentation (“Ontario Crop - Integrated Pest Control,” n.d.).

Figure 15 - Leaf with Red Spots (Source: http://www.omafra.gov.on.ca/IPM/english/grapes/diseases-and-disorders/redblotch.html)

2.1.4.3. Bacterial diseases

Sour Bunch Rot

Scientific Name: Acetobacter spp., Hanseniaspora spp., Candida spp, Gluconobacter spp.

The Sour Bunch Rot can be identified be deformation in berries as a soft watery rot, leaking juice and a distinctive vinegar and/or nail polish smell, the white grapes can turn a light brown and the red grapes can turn purplish red, pulp can totally broke and the outer membrane becomes slim, fragile (“Ontario Crop - Integrated Pest Control,” n.d.).

Figure 16 – A grape not well formed infected by Sour Rot

Crown gall

Scientific Name: Rhizobium vitis (formerly named Agrobacterium vitis)

Crown gall can be identified by their symptoms, that are swellings on the trunk that appear since the beginning of the summer, soft callus-like tissue (Figure 17), creamy in colour, going out through the bark layer near vine´s injured part, the galls formation is often seen in young vines, just above the graft union and in the end summer the galls darken and have a rough texture besides to exists for many years (“Ontario Crop - Integrated Pest Control,” n.d.).

Figure 17 - Crowngall Disease (Source: http://www.omafra.gov.on.ca/IPM/images/grapes/diseases-and-disorders/crown-gall/crowngall2_zoom.jpg?rand=61768910)

2.1.4.4. Pests

Any animal that can decimate any plant is considered a prague. There are some of them very common as beetles, spiders, mite’s thrips, and aphids. These pests can destroy any vineyards if didn’t be detected soon. But the most dangerous insect to ever attack grapevines is phylloxera, which almost ruined the world’s wine industry in the late 19th century. In that time this plague caused hectares of destruction in many vineyards fields, and the France was one of the most affected country, which almost brought the wine industry to ruin (Mailman, 2019). It is often said that this pest originated in North America and was supposedly brought across the Atlantic Ocean in the late 1850s.

Figure 18 – Vine´s leaf infected with phylloxera (Source: https://www.winemag.com/2019/05/02/wines-worst-enemy-phylloxera/)

In Portugal, the pest also devastated hectares of vineyards. Below is an illustration from the period of a French newspaper.

Figure 19 - An 1890 comic of phylloxera / getty

2.2 TECHNOLOGIES FOR THE EARLY DETECTION OF DISEASES IN VINEYARDS

2.2.1 Overview

To try to understand in how the disease can be identified and, in the future, how it can be predicted, Internet of Things devices will be used to generate more quality data to be analyzed and used into a Artificial Intelligence algorithms.

2.2.2 Internet of Things

By definition, "the Internet of Things is the concept of connecting any device to the Internet and to other connected devices."(Clark, 2016). The IoT is a network who connect everything that could connect or to be connected respond with a unique identifier, every point may collect and spread data across this net. This data is essentially about the environment around these own devices.

For this study it is necessary to understand that the actual agriculture needs on a many of physical measurement. "This is achieved through the use of sensors and IoT networks in farming. Based on this research, sensors in farming are mainly used to measure characteristics in soil, plants, atmosphere, and water."(*Seeds of Silicon: Internet of Things for Smallholder Agriculture MIT D-Lab Comprehensive Initiative on Technology Evaluation Massachusetts Institute of Technology i*, n.d.).

"The IoT has the purpose of providing an IT-infrastructure facilitating the exchange of "things" in a secure and reliable manner, i.e. its function is to overcome the gap between objects in the physical world and their representation in information systems." (Weber & Weber, 2010), so it can be applied on almost everything that people do. For example, if the alarm clock is connected in a network, can be programable to trigger an event when is deactivated and send an instruction to a coffee machine, that are also connected, starts make a cappuccino. If there a t-shirt that send an alert to a doctor when the user´s body reach 40ºC, is that another example.

3. METHODOLOGY

3.1 DESIGN SCIENCE RESEARCH METHODOLOGY

The chosen methodology for this thesis is Design Science Research methodology for IS, that can be interpreted as a way “that seeks to deliver new and innovative artefacts” developed and constructed from knowledge of science itself (Baskerville, Kaul, & Storey, 2018). DSR also “support a pragmatic research paradigm promoting the creation of artifacts to solve real-life problems” (Prat, Comyn-Wattiau, & Akoka, 2014).

There exist two laws in DSR according (Horváth, 2007) and (Baskerville et al, 2015): the first one define the utilization of the new knowledge to solve problems, generate new changes or upgrade a solution that already exists. The second, to bring new expertise, perceptions and theorical concise explanations (Pello, 2018).

Likewise, Ostrowski et al. (2012) , (Lapão, da Silva, & Gregório, 2017) amd (Peffers, Tuunanen, Rothenberger, & Chatterjee, 2007) detail this methodology in six steps process Model.

- Identify Problem & Motivation
- Define Objective of a Solution
- Design & Development
- Demonstration
- Evaluation
- Communication

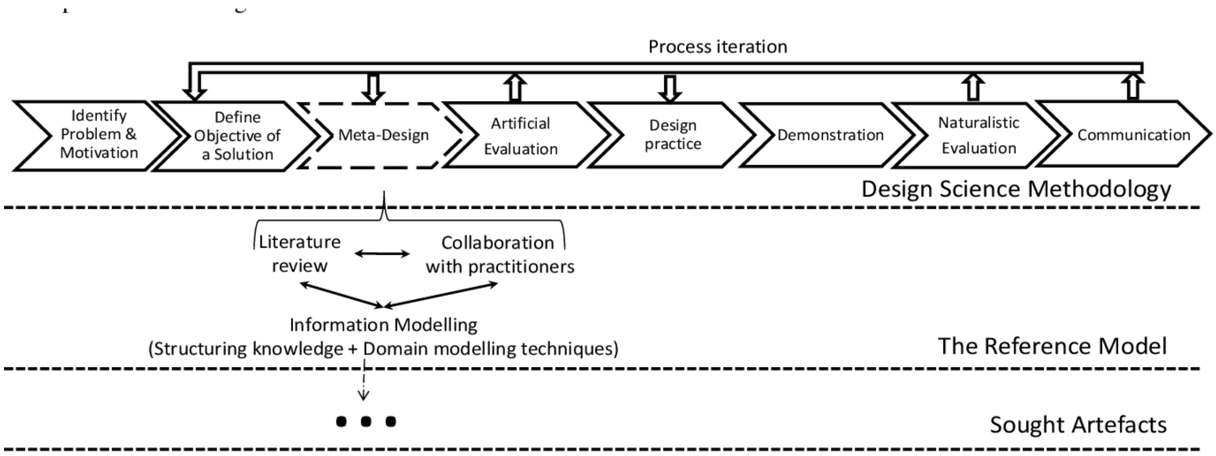

Figure 20 - Place of the Reference Model (Ostrowski 2011) in DS

3.2 Research Strategy

Step 1 – Problems & Motivations

As sections 2.1.1 and 1.2, that is already explained, the problem and motivation, respectively, this first phase highlights to define and describe the main topics of those two subjects, that detail the ecosystem around the topic (Ostrowski et al., 2012; Schorr & Hvam, 2018). In this case how the viticulture fields can be defeated be a disease and how is the impact in the human survival and economy, as a motivation to this study and help to solve the problem.

Step 2 – Objectives & Sub-Objectives Identification

The second stage aim to identify clear objectives of this research. It is recommended to identify the sub-objectives, which will help, on reaching the main one, as a step-by-step list. This information is presented in section 1.3. As described the prior objective of this dissertation is to propose an IoT IS Architecture, capable to identify the diseases before they kill the vine.

The intermediate objectives which are also part of the thesis scope are (1) to study grapes varieties in Portugal, (2) to study the most common vineyard diseases and his types, (3) to study how these diseases can be detected, (4) to study the most IoT devices. They are all detailed in Chapter 2, and sub-chapter-.

Step 3 – Design & Development (of the IS Artefact)

The third stage is focused to solve to the problem under analysis, by building the IS artefact.

Throughout the literature review, may be possible to understand there is a great concern on the student investigator to detail all the information about vineyards, Portuguese grapes variety and his types, the IoT generalization and all the detail to context the reader.

Step 4 – Demonstration of the Artefact

In this fourth activity, the artifact was shared and presented to the advisor, all the sensors and what they measure, how they work together, and how the data flows across systems, until the final user access the data, to support their decision.

Step 5 – Evaluation of the Artefact

The evaluation phase will take place by running some interviews after the demonstration, the last step. During this stage, some activities can be done to improve the proposed architecture, such as the inclusion of the

Step 6 – Communication of the Results

The object of the last stage is communicate the results of this thesis and of the developed artefact. As known this dissertation can be presented to Nova IMS as a partial requirement for obtaining the Master’s degree in Information Management.

4. AN ARCHITECTURE FOR THE EARLY DETECTION OF DISEASES IN VINEYARDS

In this chapter is proposed an innovative architecture for the early detection of diseases in vineyards using IoT sensors and AI, to support all seed-to-harvest cycle, to help the increase of grape's quality, threat early as possible the diseases.

4.1 ARCHITECTURE DESCRIPTION

Before describing the proposal architecture, a simple model is presented as an example to an IoT solution architecture. The idea is to explain how IoT devices interact with the IoT Platform by commands and events and, after that, how can integrate with an application.

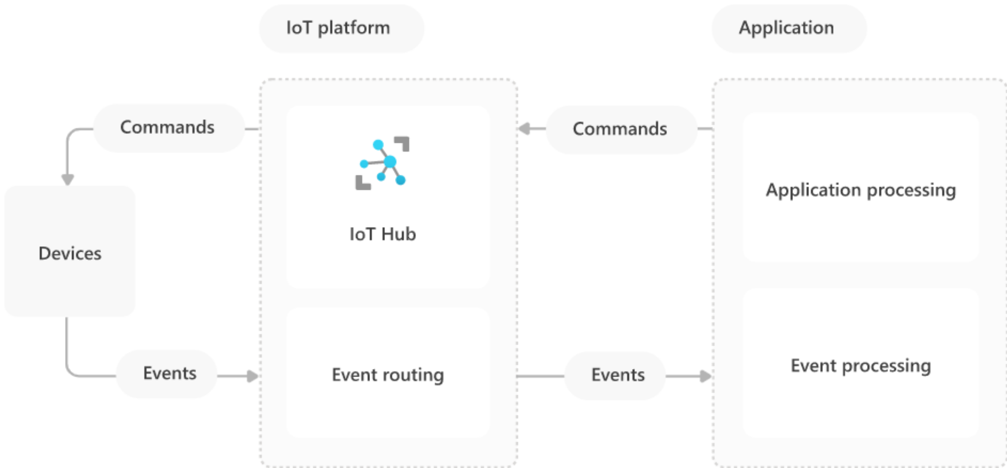

Figure 21 -MS Azure explanation of IoT Solution Architecture

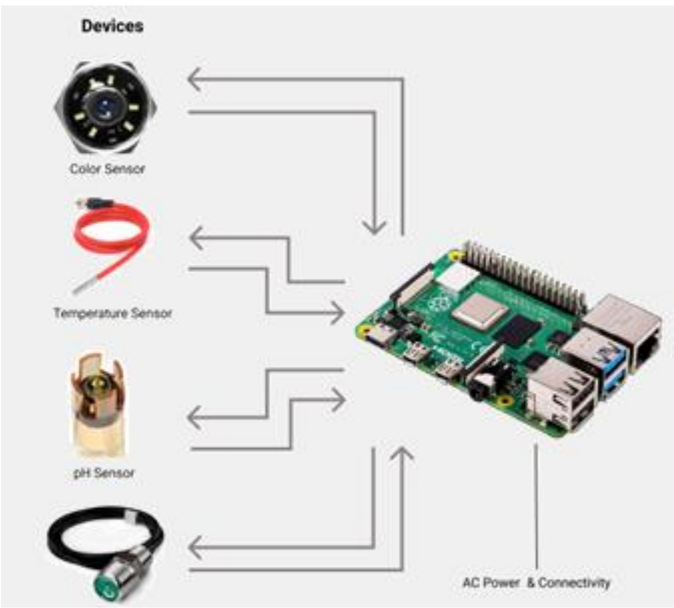

Figure 22 - Phisycal architecture

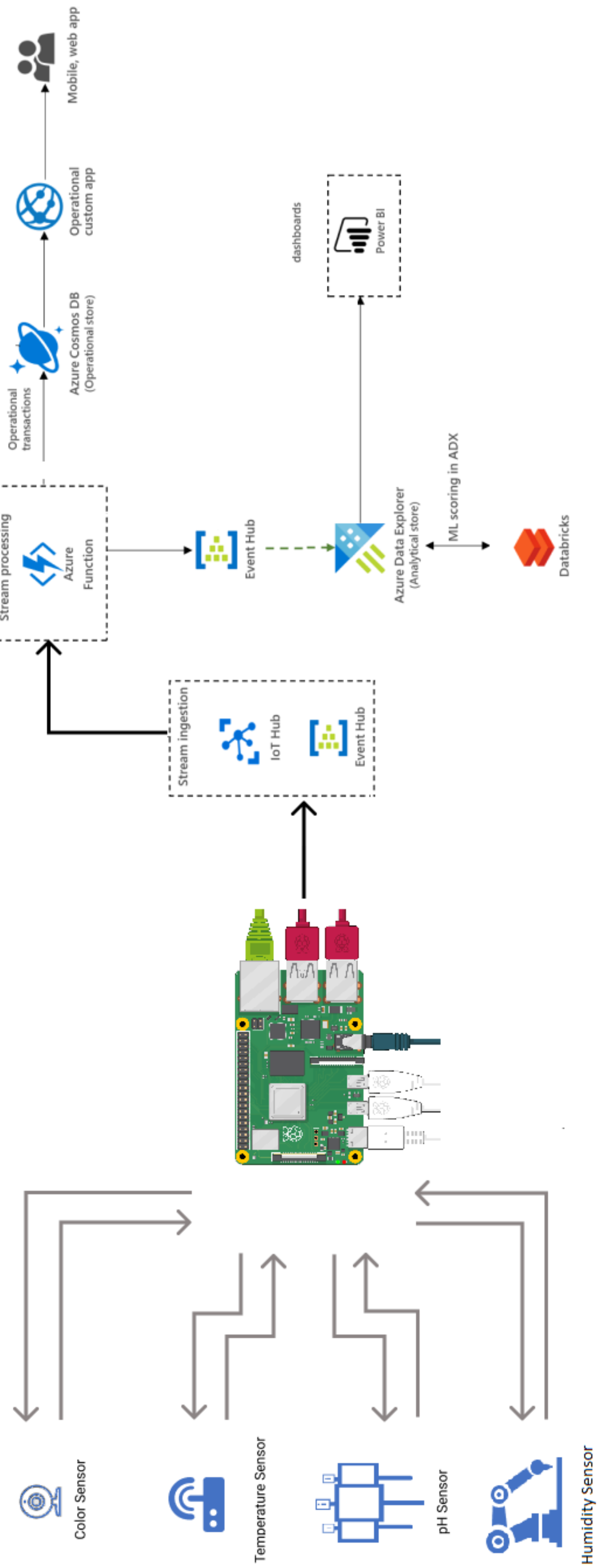

Figure 23 - IoT Architecture for early detection of Powdery and Downy Mildew diseases

4.2 DATA FLOW

The data flow starts in Sensors, IoT devices, goes to raspberry, then a server to store and analyze the collected data.

The IoT devices: Color sensor cameras, temperature sensor, pH soil sensor and humidity sensor. That data flows into the vineyard´s IoT Devices to the server.

The raspberry collect data from sensor and send execution algorithms on them, after collecting these data, they are sent to the Azure IoT Hub.

The Azure IoT Hub sends data through Azure Functions, that follow the data to Azure Data Explorer, in that point the data can follow to Azure Databricks to analyze, classify and update deep learning models.

From Azure Data Explorer it can also be connected to a Power BI instance to present the Dashboard to almost real-time statistics graphics.

From Azure Functions the operational transactions can be done throw a custom app, that can be access by a user.

4.3 COMPONENTS

To detect those plant changes, a list of specialized IoT sensors was proposed to be used. A color sensor, digital temperature sensor, ph soil sensor and humidity sensor. All these sensors are from a environmental robotics company, Atlas Scientific, and are very precise when well calibrated and configured.

4.3.1. **Raspberry**

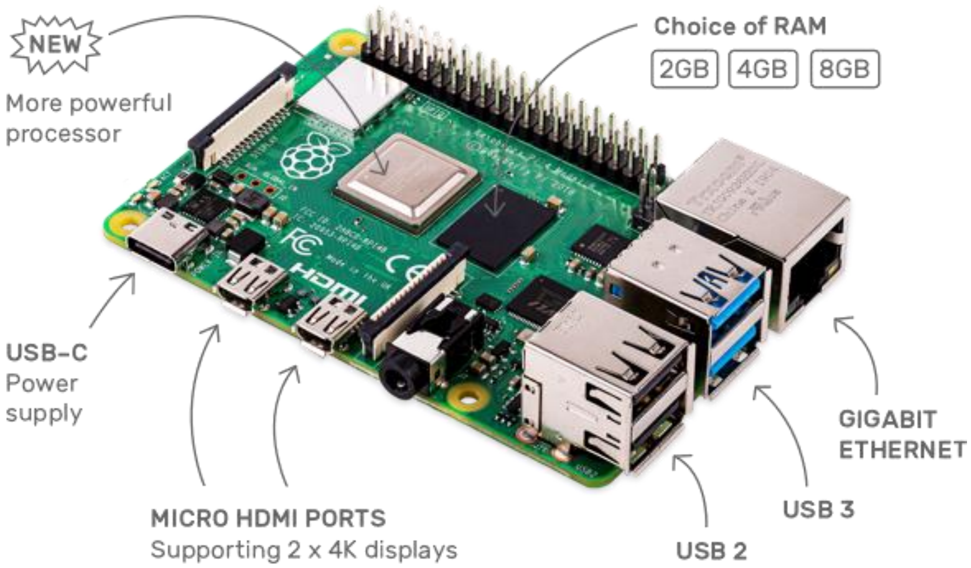

Figure 24 – Raspberry Pi 4

The raspberry will connect all sensor and deliver the data to the cloud part. It is an important phase, to connect the two worlds, it wll be responsible to send the sensors data to a cloud server to continuous the process. It is also responsible, not only to receive the sensors data, but also to execute commands on them.

4.3.2. **Color Sensor**

The color sensor will be responsible to detect the color in RGB codes. The purposed sensor model is EXO-RGB, and in the follow images it is possible to see how it is physically arranged, the white leds, that used for illumination, Infrared sensor and, in the center, the sensor itself.

Figure 25 – Left: Sensor´s cable and body. Right: Lens of Color Sensor (Source: Atlas Scientific - https://atlas-scientific.com/files/EZO_RGB_Datasheet.pdf)

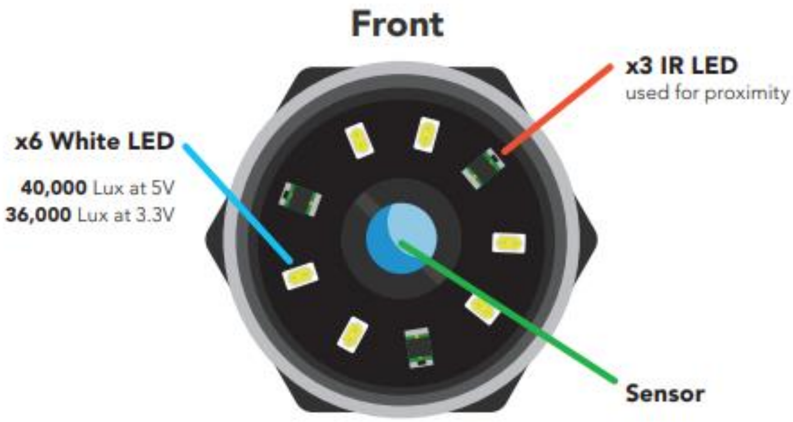

Figure 26 – Color Sensor component (Source: Atlas Scientific - https://atlas-scientific.com/files/EZO_RGB_Datasheet.pdf)

This sensor is the most important sensor in this architecture, it is responsible to detect the changes of color in a leaf, for example. This sensor has an interesting feature, that can be programmable for color matching, and it can be very useful in a very wide different grapevine. As described in documentation and how can be deducted by the part of the name “RGB”, this sensor can detect colored light in the red, green and blue spectrum. It is at least sensitive to blue light and most sensitive to red light and works form a range from 2cm up to 36 cm distance, and how closer more precise it will be the color detected.

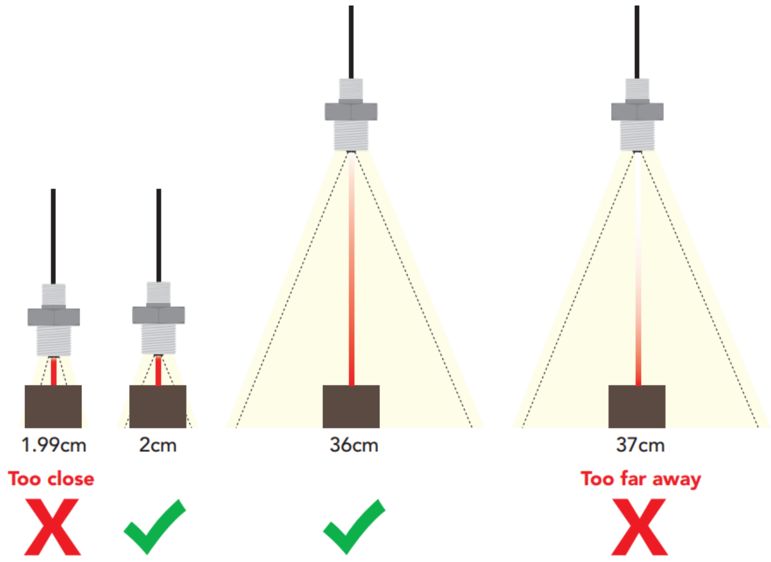

Figure 27 - Proximity sensing range ~2cm - ~36cm (Source: Atlas Scientific - https://atlas-scientific.com/files/EZO_RGB_Datasheet.pdf)

For accuracy data this sensor must be in the range presented, and the producer company strongly advice that his sensor must be mounted in a fixed location to better performance.

4.3.3. **Temperature Sensor**

The Temperature Sensor that is used in this use case is the model PT-1000, and it can be used in the soil. It is built for the temperature range from -200ºC to 850ºC, so it fits perfectly to this purpose. The reaction time is 13 seconds, with the accuracy 90% regarding producer. For this study it will be used a 30 second time duration to ensure more effectiveness.

Figure 28 – PT-1000 temperature sensor (Source: Atlas Scientific - https://atlas-scientific.com/files/PT-1000-probe.pdf)

It will be study the temperature proximity of the level ground10 and 20 centimeters above the ground.

4.3.4. **Lab Grade pH**

To measure the pH of the soil, it will be consider the generation 2 of Lab Grade pH Probe model, with double junction silver and silver chloride with EXR glass. This equipment range can variety from 0 to 14 value of pH and have a real quick response time of 1 second, delivering a value with 945% of accuracy.

Figure 29 - pH Sensor body (Source: Atlas Scientific - https://atlas-scientific.com/files/pH_probe.pdf)

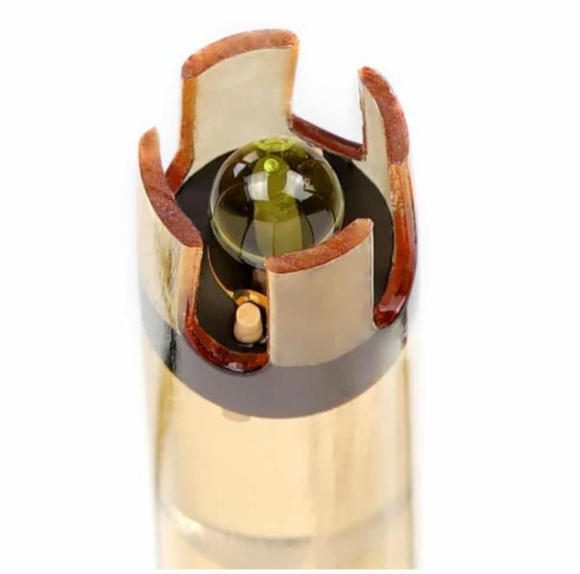

Figure 30 - pH Sensor (Source: Atlas Scientific - https://atlas-scientific.com/files/pH_probe.pdf)

The abbreviation pH means potential of Hydrogen, and this sensor can measure the Hydrogen ion activity in a liquid, in this case, in a humidity in the soil. This ion activity generates a very small current, that is proportional to the concentration of Hydrogen ions in the liquid being measures.

By definition, when a pH value is smaller than 7 the solution is classified as Acid. For the pH value equal to 7 this solution is Neutral, and when the pH value of a solution is greater than 7 is classified as a Base Solution.

4.3.5. **EZO-HUM™ Humidity Sensor**

To measure the air humidity, it is considered EZO-HUM Humidity Sensor model, and can deliver a

Figure 31 - Humidity Sensor body (Source: Atlas Scientific - https://atlas-scientific.com/files/EZO-HUM-Datasheet.pdf)

4.4 USE CASE

In order to demonstrate the architecture operation, it was selected two of the main grapevine variety, the white is Alvarinho and the red is Touriga Nacional. And the diseases selected were Downy Mildew and Powdery Mildew.

For detecting the chosen disease and type of grapes, the architecture should be calibrated with the following parameters.

Powdery Mildew

Sensor SC Color = minimum of 20 records per leaf in a range of colors

Sensor STg0 Temperature of the soil in Ground Level >= 20ºC

Sensor STg10 Temperature of the soil 10cm above Ground Level = 15ºC to 21ºC

Sensor STg20 Temperature of the soil 20cm above Ground Level = 10ºC to 16ºC

Sensor SpH pH value of the soil = < 6,7 and >7,3

Sensor SH Humidity of the soil = >60%

Detection rule for Powdery Mildew = (count(SC) > 0) + (STg0 >= 20) + (15 <= STg10 <= 21) + (10<= STg2 <= 16) + (pH < 6,7 && pH > 7,3) + (count(SH > 60) > 24)

“Powdery mildew of grape is promoted by hot (optimum temperature of 25°C), dry (but humid) weather since water inhibits germination of the conidia.” (Carisse et al., 2016)

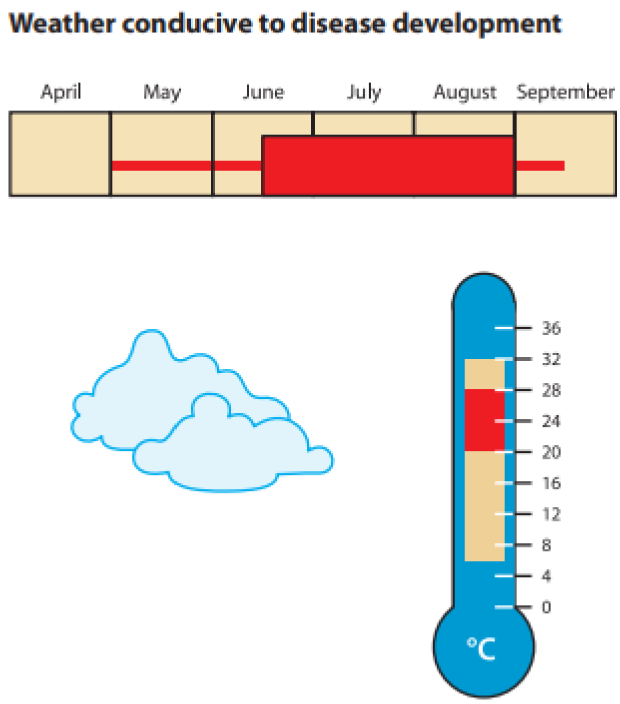

Figure 32 - Powdery Mildew better air weather condition (Source: Identification Guide to major Diseases of Grapes. Carisse et al., 2016)

Downy Mildew

Sensor SC Color = takes 20 records per leaf, return the quantity of records in a range of the infected leaves colors, for health leaf must return 0.

Sensor STg0 Temperature of the soil in Ground Level >= 10ºC

Sensor STg10 Temperature of the soil 10cm above Ground Level = 8ºC to 11ºC

Sensor STg20 Temperature of the soil 20cm above Ground Level = 6ºC to 10ºC

Sensor SpH pH value of the soil = < 6,9 and >7,2

Sensor SH Humidity of the soil (records per hour) = >85%

Detection rule for Downy Mildew = (count(SC) > 0) + (STg0 > 10) + (8 < STg10 < 11) + (6 < STg20 < 10) + (SpH < 6,9 && SpH > 7,2) + (count(SH > 85) >= 24)

The idea is to identify as soon as possible the difference values of the properties listed above and compare with data of healthy and infected vines, that way the proposed architecture can classify the new detected data.

The ideally conditions to occur the Downy Mildew is the 10:10:24 rule, that summarize the main conditions required to occur the primary infection, soil to vine. The first 10 mean that amount of rain, in millimeters, necessary to spread the fungus throw the water to a health vine-. The second numeric value, 10 again. Is about temperature, in Celsius, and the last numeric value of the rule, duration in hours, in this case, 24 hours. “Not all 10:10:24 conditions are suitable for a primary infection, but this 'rule of thumb' provides a guide to monitor for favorable primary infection conditions when no other options are available.”(Taylor, 2021).

So the main points are:

1. a wet soil, that can be detected by a Humidity Sensor (SH) for minimum of 16 hours, so the part (count(SH > 80) >= 16) means, if the count for sensor value greater than 80% is equal or greater than 16, it can an alert be emitted.
2. Rainfall achieves 3-5 mm;
3. Temperature greater than 10ºC

“The germinated oospores then release zoospores (that swim in free water) which then need to be splashed by rain or irrigation to the vine canopy before the end of the 24 hours period. This process usually requires another 3-5mm of rain (and/or irrigation) to ensure sufficient splash and leaf wetness for infection on the underside of the leaves. For this, the foliage must remain wet for at least 2-3 hours at 20°C (or 4-5 hours at 10°C) for the spores to infect the leaf and complete the primary infection cycle.”(Taylor, 2021)

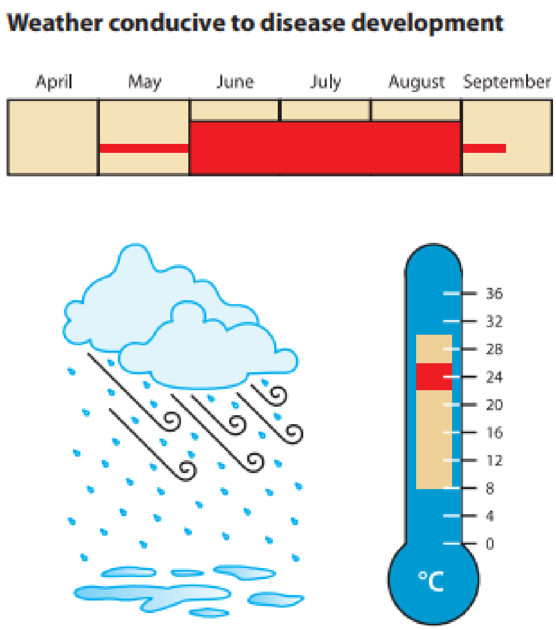

Figure 33 - Downy Mildew better condition to develop

5. CONCLUSION

5.1 Synthesis of the developed work

This exploratory study shown despite the architecture detail and much information about the symptoms and how can they be detected, this topic needs to be tested like a project to analyze the generated data. Nevertheless, the proposed IoT IS Architecture may work properly if be applied in the best possible way.

5.2 Limitations

This conceptual model was designed to detect the two chosen diseases and should be calibrated depending on the region where it will be tested.

Due the lack of time was no possible to make the planned evaluation interviews with specialists to support the architecture proposed.

Even though the research has valuable findings, some factors have implied on. First of all, the spread of the COVID-19 pandemic brought massive socio-economic impact in entire world and was not possible visit the vineyards in the Douro region and visit UTAD, Universidade de Trás-dos-Montes e Alto Douro.

5.3 Future Work

Future works can include a relevant and modern approach by image recognition, including AI methods, to increase the perception and diseases recognition accuracy. It can add computational power including more sensors and some functions to process the historical data. Expand the research to recognize other diseases is another advise for futures works.

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