Deliverable 3.1

DIAGNOSTIC DATABASE

Grant Agreement:	862848
Project Title:	Linking East and West African farming systems experience into a BELT of Sustainable Intensification
Project Acronym:	EWA-BELT
Project Start Date:	1st October 2020
Related work package:	Work Package 3
Lead Beneficiary:	OCCAM
Submission date:	31st March 2022
Nature:	Website, patents filling, etc.
Dissemination Level:	Public

This project has received funding from the European Union's Horizon 2020
research and innovation programme under grant agreement No 862848

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ACKNOWLEDGEMENT

This document is a deliverable of the EWA-BELT project. This project has received funding from the European Union’s Horizon 2020 research and innovation programme under Grant Agreement Number 862848.

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HISTORY OF CHANGES

Version	Date	Changes
REV 1	28th July 2022	To indicate and clarify the information management process of the Platform and new updates of the Database, the old paragraph "*1.4 Operation to solve phytopathological problems through the interaction with the DB*" was reformulated and divided into 3 new paragraphs. The new paragraphs describe the different phases of the Diagnosis and Prognosis of agricultural problems, specifying the functioning and processes of the Database during the use of the Platform as well as when new solutions are shared in the Planthead Network. Furthermore, a new paragraph (1.6) has been added discussing the expected future developments of the platform. The new paragraphs are: **1.4 Diagnosis System and the interaction with the Database** **1.5 Prognosis System and the interaction with the Database** **1.6 Next Step: The Automation processes** The new paragraphs contain more detailed descriptions of the processes and possible actors, screenshots of the platform and new tables. The paragraphs 1.5 and 1.6 of the old version of the Deliverable are now paragraphs 1.7 and 1.8 in the new version.

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List of Acronyms

CRUD: Create, Read, Update, Delete

DB: Database

DBMS: Database Management System

DS: District Service

FFRUs: Farmer Field Research Units

IoT: Internet of Things

NC: National Center

ORM: Object–relational mapping

PHP: Hypertext Preprocessor

qPCR: quantitative polymerase chain reaction

SP: Service Provider

SU: Service User

UML: Unified Modeling Language

URL: Uniform Resource Locator

Executive Summary

The Task 3.1 aims at implementing a remote PLANT HEAlth Diagnostic (PLANTHEAD) Network in Africa to promote real time diagnosis and environment-friendly crop protection approaches in resource-constrained environments lacking the organizational and/or the sociotechnical system resources to cope with food insecurity issues.
The proposed scheme involves an authenticated Service User (SU), who inserts the request information through a mobile phone, takes a georeferenced picture of the symptoms, submits the request to the Hub and in the meanwhile to the District Service (DS, or "First Node"). The DS validates the request, inserts further notes/attachments, provides initial feedback, and if needed submits the request to the National Centre (NC, or "Second Node", e.g., the main Universities or Research Centers). The National Center analyses the request, monitors the environmental situation, validates the request, and inserts further notes/attachments, providing additional feedback and, if needed, submits the request to the Service Provider (or "Third Node", represented by a collaborative Network of universities and research institutions with renowned expertise in plant health, epidemiology, plant disease and pest control). The Node analyses the problem, provides a diagnosis and control feedback, sends an initial solution to the National Centres (and through them, to the District Services and back to the Service User), shares the results that will update a knowledge base for intelligence services (AI-Machine Learning).
The implementation of the PLANTHEAD Network (B) will offer some important novelties:

- a capillary diffusion in remote rural areas.
- the possibility to use any system: desktop, tablet and mobile, via WEB, and with geolocation.
- profiled users with secure access and data history tracking.
- web Database to store any sort of information and georeferenced data entry with geo-visual data navigation.
- centralized data collection, validation and sharing, with user permission and restriction and workflow notification engine.
- integration with all external data sources, interoperability with external tools and scalable in functionalities.
- interoperability with IoT and intelligence services.

The PLANTHEAD approach conjugates the adoption of low cost, high throughput technologies with a web-based service for farmers, extension, and local research personnel to enable and facilitate: 1) social networking, 2) participation, 3) apomediation, 4) openness, and

5) collaboration, within and between these user groups, such as already proven in Personal Health Application Platforms[1].

PLANTHEAD Network works thanks to a **Diagnostic Database** that represents an extremely valuable tool for epidemiological studies, as it generates interactive georeferenced maps, hence allowing real time monitoring, modelling, and forecasting the progression of a pathogen or any pest that may raise serious food security/safety concerns.

[1] G. Eysenbach, *"Medicine 2.0: social networking, collaboration, participation, apomediation, and openness"*, Journal of medical Internet research, 2008. doi:10.2196/jmir.1030

The Database

1.1 The conceptualization of the Database

A database is an organized collection of structured information, or data, typically stored electronically in a computer system. The data and the DBMS, along with the applications that are associated with them, are called database system, often shortened to just database.
The Diagnostic Database of the EWA-BELT Project is modelled in rows and columns in a series of tables to make data processing and data querying efficient. As a consequence, data can then be easily accessed, managed, modified, updated, controlled, and organized. The database uses structured query language (SQL) for writing and querying data. In this case, the Database represents one of the most important elements contained in the PLANTHEAD Platform, as it is connected and interacts with all its functions. The functions of the Platform also include:

a. A space for the User roles management.
b. A space for repository where Partner can upload documents and files.
c. A space for the management of the IoT tools that will be used during the project.
d. A space dedicated to the diagnostic network, where farmers, professors, researchers, and student could exchange information through the alert function to the Service Users and Service Providers, adding images, comments, and suggestions in order to solve the phytopathological problems in the Farmer Field Research Units (FFRUs).

From a technical point of view, during the development of the Platform, it was decided that:

- The Aruba server will be used as a Server provider and, as Operating System, will be used Linux.
- The programming language will be PHP (latest version) and as framework Symfony will be used.
- Maria DB will be used as Database Management System.
- KoboToolbox will be used to collect data, surveys and to receive pictures from the field, contributing to feed the Diagnostic Database.

OCCAM proceeded with the design of all the possible applications contained in the platform. The development process of the Platform has been analysed in terms of costs, time, and results to be achieved. The creation of the Database started when the African partners began to collect data on the field (FFRUs) with survey previously deployed by OCCAM using KoboToolbox. During the collection of data, OCCAM improved the use of KoboToolbox and solved some issues regarding the storage of data, the data export from KoboToolbox, and how to move forward the engagement of a Developers and the depiction of the detail using an UML scheme.

1.2 The Development of the Database

Respecting the principle of the best value for money, OCCAM subcontracted IT professionals with an expertise in the platform development using the Symfony framework. The programming and development work was divided into several Phases, with the respective Tasks.

The following Tasks emerged for the Phase 1:

1. Configuration of the development environment, creation of the repository and configuration of the deploy procedure for implementing safe start-up on the host server.
2. Installation and configuration of the PHP Symfony Framework and integration with the deploy procedure.
3. Configuration of the graphic template within the Symfony Framework.
4. Configuration and management of users with different roles, authentication methods and system functionalities.
5. Creation of role-based differentiated menus.

The following Tasks emerged for the Phase 2:

1. Creation of the whole of CRUD to add, edit, delete, and view the system entities. The creation of the CRUD consists in the creation of all the screens and all the forms for inserting, editing, and deleting all the elements of the system, therefore users, nodes, WPs, and tickets. Hence, all the forms will be created with the necessary fields and the screens that will allow admin users to manage everything via the admin panel, including insertion, update, and deletion.
2. Management and creation of the ticketing system, i.e., a registry created within the Platform that shall include all the requests for assistance sent by farmers (three alert modes with management of request at different nodes).
3. Possibility to manage nodes based on geolocalization with standard configuration and subsequent manual edits based on needs.
4. Creation of a panel to create association to different forms, offering a direct link to users to fill out the survey. The system will offer a mapped survey list with the direct URL to the KoboToolbox.

1.3 Structure of the Database

The Database of the PLANTHEAD Platform is within the virtual server hosted using the Aruba service provider, in Italy. The project source code and the web server are also contained in the same server.

The Database interacts with the application through:

- User registration and login through the login and registration forms.
- Management of user authorization roles on the platform.
- Management of partners with which the user registers by associating with a partner already entered in the system or by entering a new one.
- Management of the Forum
- Management of alert processes, with which it is possible to manage in turn all the nodes that will be used to manage alert tickets.
- Management of the Nodes which allows to create the respective folders in the files repository.
- Management of alert tickets, giving the user the opportunity to report problems encountered and resolve them by the Nodes.
- Repository: the ability to create folders and subfolders, in turn add files and modify their access level through the roles created in the system.

Technical explanation of the ways of interaction between Database and other functions of the platform: It is possible to access the Database only through credentials. The interaction with the application is developed using PHP source code with ORM Doctrine of the Symfony framework used to build the platform.

1.4 Diagnosis System and the interaction with the Database

The Diagnostic System in the PLANTHEAD Platform is conceived to be as intuitive as possible, based on the principle "*send request – receive solutions*". The request is formulated by the Service Users (SU) and is received by the entire Planthead Network. The SU could be the Farmer in the FFRU or Extension Services providing support to the latter. The request sent through the Platform is called "Alert" or "Ticket". To be more specific, when a User needs any form of agricultural support or a specific diagnosis for a phytopathological problem, she logs-in into the Platform and sends an alert through the slider (*Table 1*).

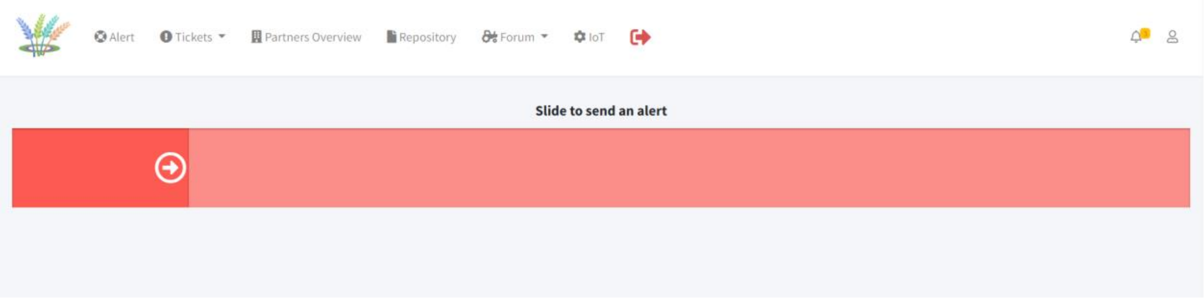


Table 1: Slider to send an Alert

Beside the Alert, the Service Users or the Extension Services can upload within the Database further information regarding the problem they are dealing with, by adding any additional material/evidence that could be useful to make a diagnosis and receive a prognosis. To add information, a specific feature visible in the window below (*Table* 2*)* has been developed.

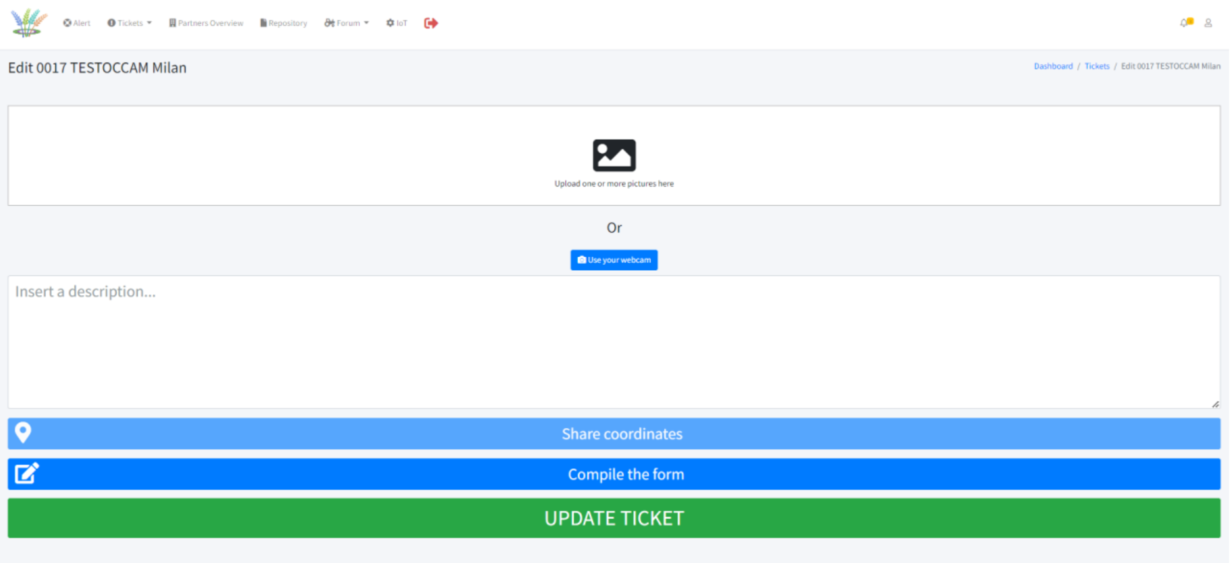


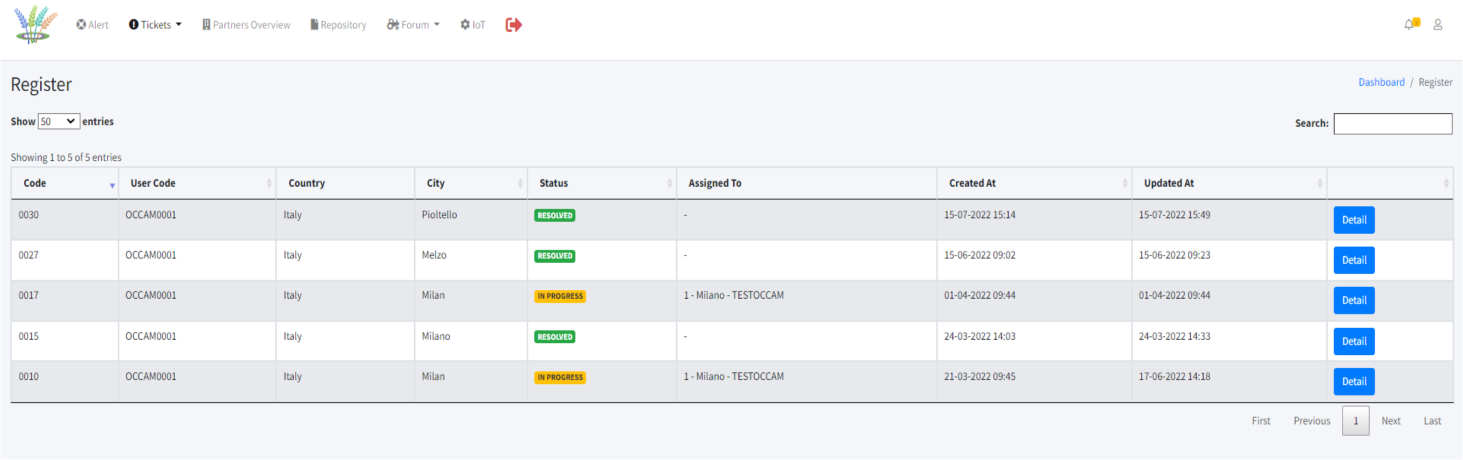
Table 2: Window to update additional information

The additional information that could be uploaded include:

1. One or more **photos** of the issue affecting the Service User. Once uploaded by the Service User, the photos are physically stored in the "Image Repository" and will be used by other users to carry out a diagnosis or to resolve, with more precision, any agricultural problem the farmer has incurred so far.
2. **Description** or comment of the problem, to provide a written overview.
3. **Geolocation**, to know where the problem/farmer/request of assistance is located.
4. With the support of an agronomist or an expert user, the Service User can fill in the **diagnostic form**. This form contains very specific scientific information, and it is useful to make a complete diagnosis.

The Alert (with the additional information described above, if inserted) is received either by a Partner of the Consortium, a Research Center, or an Extension Service. The receivers of the Alert are called "**Nodes**". The design of the Node Scheme was carried out trying to provide widespread support to the research activities in the FFRUs in different countries using a bottom-up approach, with Local Nodes, National Nodes, and International Nodes, considering the different skills and experts of the project partners related to the problems that will affect the farmer. When a Service User sends an Alert, the latter is sent to the closest Node in geographical terms or to a specific partner able to solve the problem (such as a pathologist rather than an agronomist or others). The first receiver is called "**First Node**". Each country can contain from one to more "First Nodes". All "First Nodes" in a Country, connected through the Platform, create the "**Second Node**". Finally, all the Partners of the Consortium and the Research Centers of the project create the "**Third Node**".

All the information uploaded on the platform (ticket with photos, descriptions, geolocation, scientific information) will be received by the Node and will be also collected and stored in the Diagnostic Database. The Database updates itself automatically every time new information is received. In the DB, the Ticket is catalogued as "in progress" (with a yellow tag) when it does not contain a solution yet, and as "resolved" (with a green tag) once request of assistance forwarded by the farmer has been successfully answered by the Node. At this point, the Database contains and stores all the information. All alerts and the information contained in it are visible in the "Ticket Register" (*Table 3*).



Register

Show 50 entries

Search:

Showing 1 to 5 of 5 entries

Code	User Code	Country	City	Status	Assigned To	Created At	Updated At	
0030	OCCAM0001	Italy	Pioltello	RESOLVED	-	15-07-2022 15:14	15-07-2022 15:49	Detail
0027	OCCAM0001	Italy	Melzo	RESOLVED	-	15-06-2022 09:02	15-06-2022 09:23	Detail
0017	OCCAM0001	Italy	Milan	IN PROGRESS	1 - Milano - TESTOCCAM	01-04-2022 09:44	01-04-2022 09:44	Detail
0015	OCCAM0001	Italy	Milano	RESOLVED	-	24-03-2022 14:03	24-03-2022 14:33	Detail
0010	OCCAM0001	Italy	Milan	IN PROGRESS	1 - Milano - TESTOCCAM	21-03-2022 09:45	17-06-2022 14:18	Detail

Table 3: Ticket Register

The Ticket Register can be consulted both by the Node that oversees the request, by all the other Nodes in different Countries, and by other Users, who will be able to use the knowledge stored and consult the other requests to create a Network.

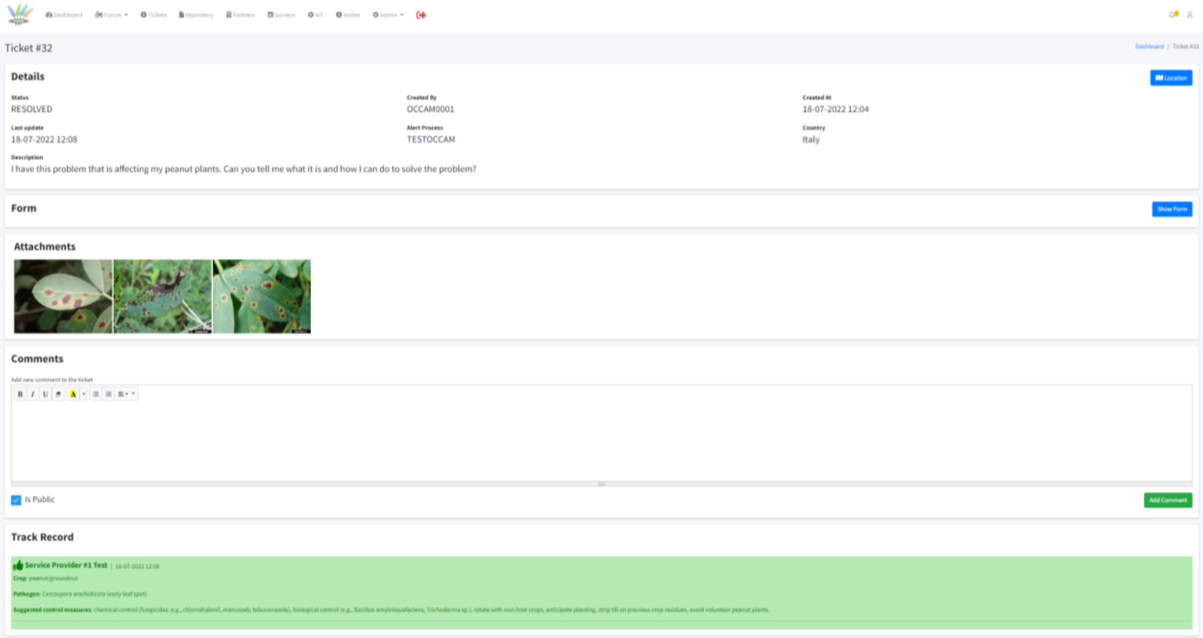
The Ticket register shows a series of information in the columns, including:

1. The ticket codes.
2. The code of the user who sent it.
3. The country and the city from which it was sent.
4. The status of the request ("in progress" or " resolved").
5. The Node in charge to solve the request.
6. Date and time when the alerts have been created.
7. Date and time when the alerts have been updated.
8. The "Detail" button, to view the information and to make the diagnosis.

The Database contains the information, allowing Service Providers or other Service Users to upload new comments and observations to support the diagnosis process carried out by experts.

1.5 Prognosis System and the interaction with the Database

When the diagnosis of the problem is made by experts and through the help of the Planthead Network, the therapy and the relative prognosis will be elaborated by scientists and experts in the Research Centers and Universities resulting in a specific protocol. Once the protocol has been identified, the farmers will be automatically notified through a communication system developed within the platform as well as with a notification on their indicated email. At this point, the protocol could be applied in the FFRU for further experimentations. When the protocol proves to be a resilient and replicable solution to the problem it was created for, it will be validated by the experts or by the Research Centres/Universities, becoming a certified *best practice*. The *best practice* is uploaded manually into the database by the staff of the First Node. Hereinafter, the solution will be displayed in green in the “Ticket Details” (*Table 5*).



Ticket #32

Details

Status
RESOLVED

Created By
OCCAM0001

Created At
18-07-2022 12:04

Last update
18-07-2022 12:08

Alert Process
TESTOCCAM

Country
Italy

Description
I have this problem that is affecting my peanut plants. Can you tell me what it is and how I can do to solve the problem?

Form

Attachments

Comments

Add new comment to the ticket

☑ Is Public

Track Record

Service Provider #1 Test | 18-07-2022 12:08

Crop: peanut/groundnut

Pathogen: Cercospora arachidicola (early leaf spot)

Suggested control measures: chemical control (fungicides: e.g., chlorothalonil, mancozeb, tebuconazole), biological control (e.g., Bacillus amyloliquefaciens, Trichoderma sp.), rotate with non-host crops, anticipate planting, strip till on previous crop residues, avoid volunteer peanut plants.

Table 4: Ticket Details with Solution to the problem (in green)

In the Ticket Register, the status of this request will be flagged as "Resolved". The solution of that specific problem will be visible to all Users who may therefore consult it and extrapolate the same prognosis, the suggested control measures, and all *best practices*. All the diagnoses and the solutions in the Diagnostic Database constitute the knowledge base for further automatization processes and intelligence services.

1.6 Next Step: The Automation processes

An automation system designed to be developed within the PLANTHEAD Platform consists of a software who allows to provide control measures, *best practices*, or adequate therapy solutions automatically when the diagnosis to farmer's ticket has been validated by Nodes. The Diagnostic Database is set up to contain and interact with this automation software. The development of the software starts as soon as the Database will be filled with alerts, diagnosis, prognosis, and *best practices* by Users of the Platform. It is expected that, with the increase of data, some technical specifications of the platform will be implemented through new hardware and software developments.

The Artificial Intelligence and Machine Learning system for Image Recognition of Plant Diseases is a possible automation system, but not envisaged by the EWA-BELT project. However, OCCAM and NRD have decided to start developing and testing an AI model from scratch. For the experimentation, four leaf diseases of peanut plants have been tested so far. Each disease corresponds to a class. The four diseases chosen for now are "Cercospora Arachidicola", "Cercosporidium Personatum", "Phoma Arachidicola", and "Puccinia Arachidis", plus the "Healthy" class (*Table 6*).

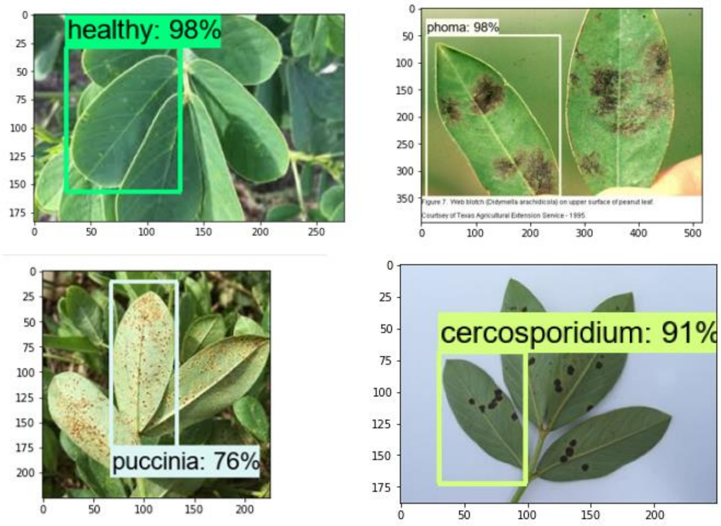


Table 5: Experimentation of Image Recognition of Peanut Leaf Diseases

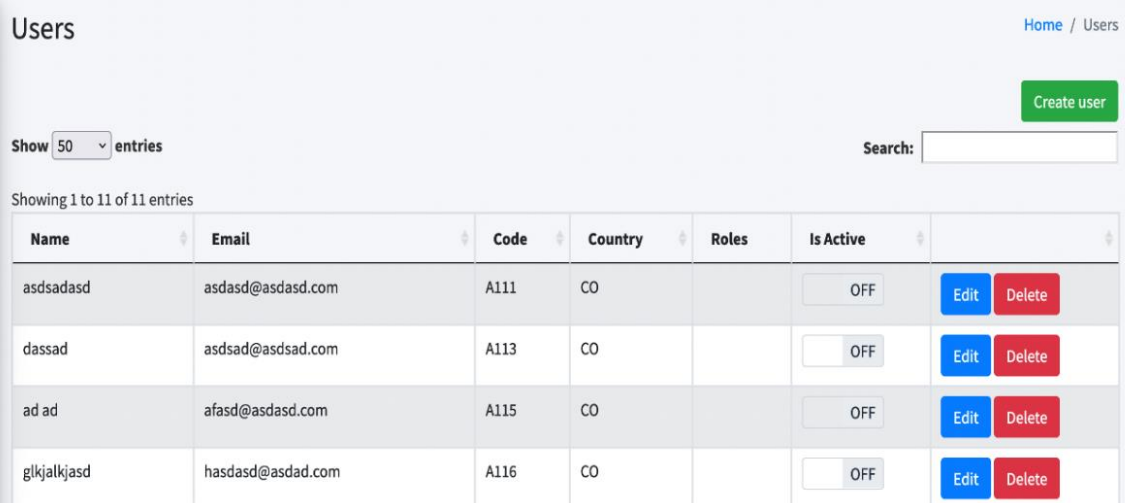
If the experimentation is successful, this system will allow us to test the reliability and validity of Artificial Intelligence solutions for plant diagnostics. The faculty foresees to start dialogues with possible external institutions and stakeholders who have already developed similar artificial intelligence systems soon so to create and deploy the best AI model possible.

1.7 Technical specifications

Services	Version	Use
NGNIX	1.10	Web server
PHP	8.1	Server-side programming language
MariaDB	10.7.3	Database Server
Symfony	5.0	PHP framework used to build the application
Javascript		Client-side programming language
jQuery	3.0	Javascript library
HTML	-	-
CSS	-	-
Bootstrap	4	CSS Framework

Services	Use
Google Maps	Geocoding of the city in coordinates
IpStack	Geocoding service through IP address
Mailgun	Email provider service

Technical specification of the hardware
Shared VPS
Debian9 64bit
2vCPU
4gb RAM
10gb Hard Disk



Users

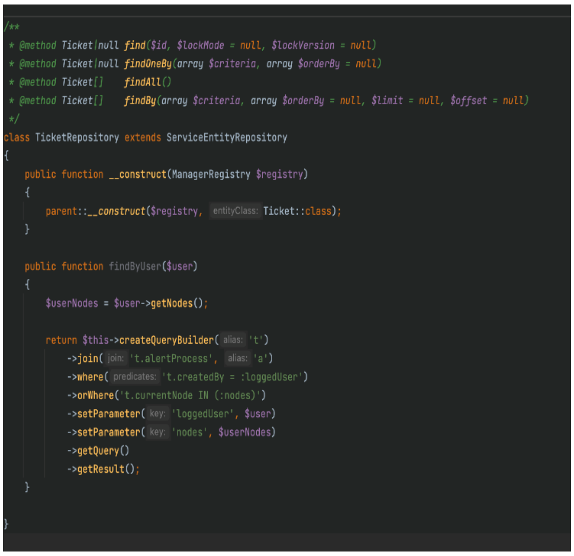
Show 50 entries

Search:

Showing 1 to 11 of 11 entries

Name	Email	Code	Country	Roles	Is Active	
asdsadasd	asdasd@asdasd.com	A111	CO		OFF	Edit Delete
dassad	asdsad@asdsad.com	A113	CO		OFF	Edit Delete
ad ad	afasd@asdasd.com	A115	CO		OFF	Edit Delete
glkjalkjasd	hasdasd@asdad.com	A116	CO		OFF	Edit Delete

Table 6: Example of the frontend picture of the settings



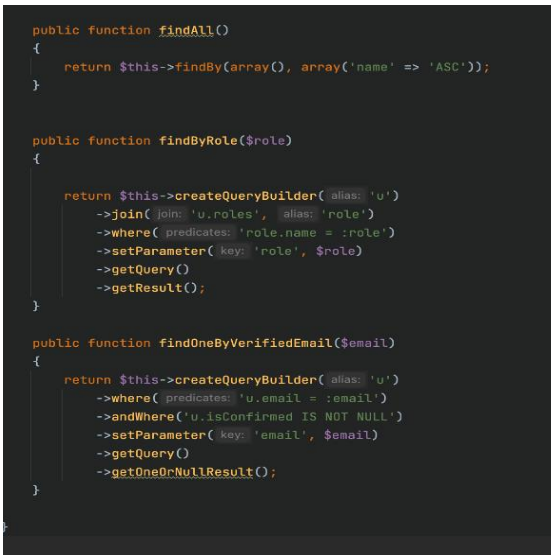
```
/**
 * @method Ticket|null find($id, $lockMode = null, $lockVersion = null)
 * @method Ticket|null findOneBy(array $criteria, array $orderBy = null)
 * @method Ticket[]    findAll()
 * @method Ticket[]    findBy(array $criteria, array $orderBy = null, $limit = null, $offset = null)
 */
class TicketRepository extends ServiceEntityRepository
{
    public function __construct(ManagerRegistry $registry)
    {
        parent::__construct($registry, entityClass: Ticket::class);
    }

    public function findByUser($user)
    {
        $userNodes = $user->getNodes();

        return $this->createQueryBuilder( alias: 't')
            ->join( join: 't.alertProcess', alias: 'a')
            ->where( predicates: 't.createdBy = :loggedUser')
            ->orWhere('t.currentNode IN (:nodes)')
            ->setParameter( key: 'loggedUser', $user)
            ->setParameter( key: 'nodes', $userNodes)
            ->getQuery()
            ->getResult();
    }

}
```

Table 7: Example of the Backend picture of the source code



```
    public function findAll()
    {
        return $this->findBy(array(), array('name' => 'ASC'));
    }


    public function findByRole($role)
    {

        return $this->createQueryBuilder( alias: 'u')
            ->join( join: 'u.roles', alias: 'role')
            ->where( predicates: 'role.name = :role')
            ->setParameter( key: 'role', $role)
            ->getQuery()
            ->getResult();
    }

    public function findOneByVerifiedEmail($email)
    {
        return $this->createQueryBuilder( alias: 'u')
            ->where( predicates: 'u.email = :email')
            ->andWhere('u.isConfirmed IS NOT NULL')
            ->setParameter( key: 'email', $email)
            ->getQuery()
            ->getOneOrNullResult();
    }

}
```

Table 8: Example of the Backend picture of the source code

1.8 Database management and further development

OCCAM and UNISS manage the elements within the Database and the frontend structure, while the technical infrastructure will be updated and may be developed by IT professionals from OCCAM, following the needs and the development of the platform and the activities of the consortium.