D1.8
Integrated factory digital twin designer on RAMP 2.0 version 1.3

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Abstract

This document is the second release, on M30, of the document “Integrated factory digital twin designer on RAMP 1.0”, officially released as D1.8. First release was on M12 as D1.2. A final release will be produced on M45 of the project.

The document’s aim is the “Integration of the APM in the RAMP Marketplace and a guide how to use it” and is the output of Task “T1.2 Factory digital twin designer”, M1-M45.

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Notification

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20-03-2023	1.3	Giorgos Altanis	Review

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EXECUTIVE SUMMARY

This document is the second release, on M30, of the document “Integrated factory digital twin designer on RAMP 1.0”, under the official designation of D1.8 (first release was D1.2). The final release will be produced on M45 of the project. The document’s aim is the “Integration of the APM in the RAMP Marketplace and a guide how to use it” and is the output of Task “T1.2 Factory digital twin designer”, M1-M45.

The Advanced Plant Model (APM) is a system developed by INESC TEC that aims to provide a “real-time” digital representation of the ongoing state of a given shop floor, in the form of semantic and geometric information. It includes representations of workers, industrial and mobile robots, work-stations, manufacturing lines, racks, boxes, palettes, kits and parts, consolidated by a production schedule generated by a Manufacturing Execution System (MES). Human operators and robotic manipulators can exploit this information when participating in manufacturing operations on the shop floor.

The Digital Twin Designer, described in this document, is the element inside the APM system that provides the means which enable the User to build a digital representation of manufacturing areas, including their major objects such as logistic racks, robotic manipulators and equipment is general, among others. CAD models representing the objects available in the manufacturing area may be selected and entered into the system in order to achieve a digital model of the three-dimensional environment. Main users of the Digital Twin Designer include management workers from Manufacturing SMEs and system integration engineers from Technology Providers, which may exploit all the functionality provided by the APM.

This document provides a User Manual of the Digital Twin Designer, describing the main application features of the Tool and a set of training material, oriented to the User and letting him/her experience the main functions implemented by the Tool.

Furthermore, the document reports the technical integration achieved with the following Better Factory solutions:

- Advanced Production Planning and Scheduling (APPS) Production Reconfiguration package – in this regard, the APM allows the Manufacturing Process Management System (MPMS) to integrate robotic manipulators (mobile / fixed) in the enactment of manufacturing processes.
- Open Platform for Innovations in Logistics (OPIL) – the APM provides two main functions: 1) enabling the OPIL user to generate the required digital artefacts for OPIL specifying the layout and main physical objects present in a manufacturing environment and 2) providing a real time 3D visualization of the navigation of OPIL robots.
- RAMP IoT Platform – the connection of the APM with the RAMP IoT Platform allows the communication between the OPIL robotic agents and the APM, to enable the 3D visualization of AGVs in the digital representation of the shop floor.

1 Introduction

1.1 Scope and objectives

This document is the first release on M30 of Deliverable D1.8 “Integrated factory digital twin designer on RAMP 1.0”. Previous release was the D1.2 on M12. Final release will be on M45 of the project.

The document’s aim is the “Integration of the APM in the RAMP Marketplace and a guide how to use it” and is the output of Task “T1.2 Factory digital twin designer”, M1-M45.

The Advanced Plant Model (APM), which includes the Digital Twin Designer, is a system developed by INESC TEC that aims to provide a real-time digital representation of the ongoing state of a given shop floor, in the form of semantic and geometric information. It includes representations of workers, industrial and mobile robots, work-stations, manufacturing lines, racks, boxes, palettes, kits and parts, consolidated by a production schedule generated by a Manufacturing Execution System (MES). Human operators and robotic manipulators can exploit this information when participating in manufacturing operations on the shop floor.

1.2 Document organization

Besides the executive summary and this introduction, the document is organized in the following chapters:

- Chapter 2 “The Advanced Plant Model and the Digital Twin Designer” – supplies an overall description of the APM and of the Digital Twin Designer, identifying their relationship;
- Chapter 3 “Methodology” – specifies the methodology one should follow to create a digital model on the Digital Twin Designer;
- Chapter 4 “Integration with RAMP” – identifies the elements that were addressed in the integration of the Digital Twin Designer in the RAMP Marketplace;
- Chapter 5 “Integration with RAMP IoT Platform and APPS” – identifies the elements that were addressed in the integration of the Digital Twin Designer in the RAMP Marketplace;

Chapter 0 “

- Integration with robotic agents (via OPIL)" – describes the integration with the OPIL solution;
- Chapter 7 "User Manual" – aims to describe all the relevant functional and graphical elements in the Digital Twin Design that enable Users to create digital models;
- Chapter 0 "

- How to" – provides a series of "how to" cases aiming to provide Users working examples on the usage of the Digital Twin Designer;
- Chapter 9 "Conclusions" – concludes the report by identifying the major developments and next steps.

In the end, Annex A provides samples of the digital artefacts generated for the OPIL solution and Annex B samples of OPIL ROS messages that are processed by the APM.

1.3 Acronyms

Acronym	Term
AGV	Automated Guided Vehicle
APM	Advanced Plant Model, name of the software-based system that includes the Digital Twin Designer
APPS	Advanced Production Planning and Scheduling
MES	Manufacturing Execution System
OPIL	Open Platform for Innovations in Logistics
OSPS	Open Scalable Production System, architecture framework specifying the relationship of a set of software elements aiming to manage a scalable production system
PLY	Polygon File Format, data format for CAD models
RAMP	Robotics and Automation Market Place
RAN	'Robot Agent Node', element belonging to the OPIL solution
STEP	STandard for the Exchange of Product model data, ISO 10303, data format for CAD models
STL	Standard Triangle Language, data format for CAD models
URDF	Unified Robot Description Format, data format for CAD models
MPMS	Manufacturing Process Management System

2 The Advanced Plant Model and the Digital Twin Designer

The Advanced Plant Model (APM) is an autonomous software-based system that aims to manage a near real-time digital representation of the ongoing state of a given manufacturing area with the main purpose of controlling and monitoring the operations carried out by a fleet of fixed and/or mobile robotic manipulators that carry on logistic and assembly operations.

The model maintained by the APM comprehends the three-dimensional information about the geometry of major objects present in the shop floor, such as Racks, Boxes, Palettes and Kits in the case of a logistics area and Workstations, Conveyors, Equipment and Manufacturing Lines in the case of an assembly line. The CAD models of the parts that are manipulated and/or assembled are also included in the Model, together with the corresponding grasping poses.

Robotic Manipulators are modelled in terms of three-dimensional geometry but also in terms of their capabilities to operate on the shop floor and to execute logistic and assembly tasks. In particular, the robotic programs are also kept in the Advanced Plant Model and downloaded to the robots when needed.

The third aspect that links together the two above ones, is the production schedule. Instances of production schedules may be retrieved from a Manufacturing Execution System, specifying the operations to be achieved, their sequence and the assignment of production resources (human operators, robots, other equipment). The Advanced Plant Model integrates the robotic programs in the production plan and interacts with them in order to instruct them to execute the assigned manufacturing/logistic tasks and to monitor their execution. During the execution of a task by a robot, the Advanced Plant Model provides information to the robot, stating the location and geometry of all the objects that will be used in the context of that task, fulfilling the main purpose of the system which is to provide information about the ‘world’ to the robot fleet.

The communication model between the APM, the robot fleet and the MES is specified by the OSPS framework (Open Scalable Production System). Communication between these elements is achieved through the exchange of messages and via a publish-subscribe mechanism.

The Digital Twin Designer name identifies the element inside the APM, that enables Users to build the digital representation of a physical area (logistics, assembly, etc.) by creating 3D models of objects, such as racks and workstations, and to provide a 3D visualization of the Model for other purposes not initially envisioned by the Advanced Plant Model.

This document addresses the Digital Twin Designer, the main functionality of the APM as weel as its integration in the RAMP Marketplace, and with the Advanced Production Planning and Scheduling (APPS) Production Reconfiguration and Logistics Automation and Optimization packages. Integration with the RAMP IoT is also addressed.

3 Methodology

The Digital Twin Designer assumes that the User knows very well the layout of the physical area that he/she intends to represent in digital form as well as the functional and geometric characteristics of the physical objects located in the physical area. These objects may be racks, palettes, conveyors, workstations, production lines, robotic manipulators, and equipment in general. Before the Users start using the Tool they must get acquainted with the physical reality of the targeted area.

Subsequently, the User should:

1. Build a Catalogue comprehending the geometry of each type of physical objects he/she needs to insert in the final Model. CAD models should be retrieved from external sources (either from public repositories available in the Internet, from the company's own CAD/CAM system or from the equipment manufacturers). Section 7.4 addresses this step.
2. Create a Map that specifies the layout of the target physical area. Create the 'physical area' object by specifying its dimension, scale and map.

   Section 7.5.1 addresses this step.
3. Start populating the Map with instances of objects, by selecting objects on the Catalogue and implanting them on the image representing the Map.

   Section 7.5.2 addresses this step.
4. Validate the locations where objects were implanted, by looking at the entire model in a three-dimensional window.
   Section 7.5.3 addresses this step.

Initial training is essential for the user to know concretely what he/she can do with the Tool and how to do it. Section 0 addresses this need.

In this usage scenario, Users of the Digital Twin Designer may include any human worker with management responsibility working for the Manufacturing SME that is being targeted for modelling. Additionally, and depending on the specific case at hand, workers from the Technology Provider serving the Manufacturing SME may also be Users of the Digital Twin Designer. The artists, as defined by Better Factory, are not intended to use the Digital Twin Designer.

4 Integration with RAMP

The Advanced Plant Model and the included Digital Twin Designer is an autonomous system, implemented by two components. One implements the front-end of the system, using web technologies such as HTML 5, the JavaScript language and several Open Source JavaScript frameworks. This component is connected to a back-end component, implemented by Java technology and related Open Source frameworks. A REST based API lets the front-end interact with the back-end. An external Database Management System provides the data storage and access.

In order to maintain this structure and restrict the changes to the minimum possible, integration of the Digital Twin Designer in the RAMP Marketplace takes the form depicted on Figure 1:

- A Docker based infrastructure was setup to hold several instances of the APM system (left part on the Figure). Each instance of the system is to be assigned to a distinct company specified in the RAMP Marketplace, so that there is no data sharing between the models built by Users of different companies.
- A single Database Management System (Mongodb) manages all the instances of the APM. A different database is assigned to each APM instance.
- The front-end of the APM, running on an HTML browser, is embedded into an HTML frame created by the RAMP Marketplace. The User launches the front-end by clicking a button inside a window within the RAMP user interface. An HTML 5 frame is created by RAMP with the APM's front-end is embedded inside.
- User authentication is started by the APM but actually is accomplished by the RAMP Marketplace, by implementing the OAuth 2 protocol.
- Finally, the user interface of the APM was adapted in order to comply with the RAMP identity, that specifies the form of the visual elements in RAMP (logo, typography, background and foreground colours, etc.).

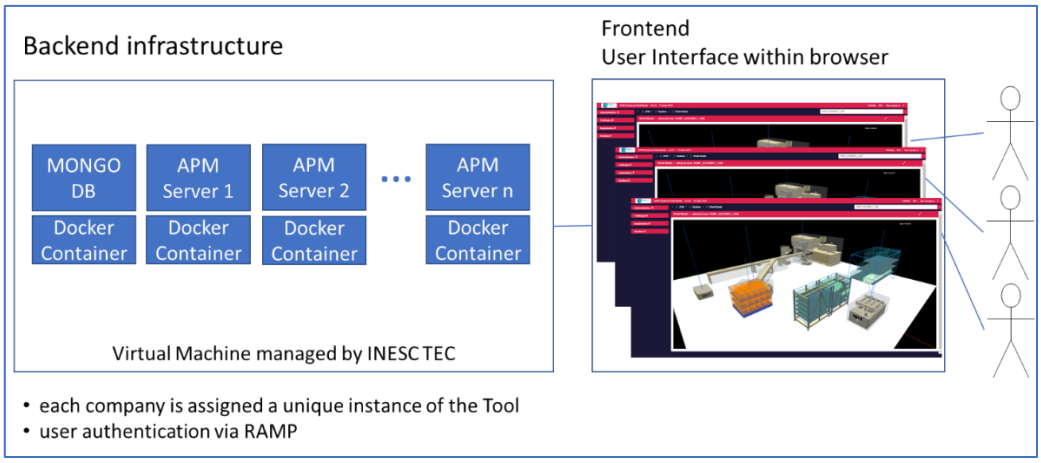


Figure 1 - Digital Twin Designer integration in RAMP

Figure 2 – First refinement of the APM interface to comply with the RAMP identity

5 Integration with RAMP IoT Platform and APPS

The Advanced Plant Model (APM) is a system intended to build and maintain a digital representation of a manufacturing or logistic area for the main purpose of controlling and monitor the operation of a fleet of robotic manipulators operating in such working spaces. A set of communication messages, part of the Open Scalable Production System (OSPS) framework, which allow the APM to communicate with a Manufacturing Execution System (MES) and a fleet of robotic manipulators, had already been defined before the launch of Better Factory. In relation to the MES system, the APM retrieves a production plan that is then consolidated with the digital representation of the manufacturing/logistic area. This consolidated plan, which specifies the tasks to be accomplished by a set of robotic manipulators, is then executed by the APM, by sending the tasks to the assigned robots, in the order specified by the plan, and by monitoring its execution. Additionally, information about the digital representation of the 3D space is supplied to each robotic manipulator, in a task-oriented way, i.e. the APM only supplies the information that is relevant for the accomplishment of a manufacturing/logistic task.

Communication between MES, APM and robotic manipulators is achieved through a publish-subscribe communication model, handled by an intermediate system, the publish-subscribe communication broker. In the past years, two communication brokers have been used, the Apache Kafka and the Manufacturing Service Bus. In the realm of the Better Factory project, the RAMP IoT Platform, which includes the FIWARE Orion Context Broker, is the element responsible for enabling the communication between the physical elements in a given manufacturing or logistic area and the applications that manage parts of the production system, such as the ones planned for the Advanced Production Planning and Scheduling (APPS). As such, communication between the APM (element provided in the co-creation space of the RAMP Marketplace) and the APPS is to be enabled by the ORION Context Broker.

During the first year of the project, technical integration was developed on the APM so that data items, encapsulated in messages, could be published and retrieved from the Orion Context Broker. As examples, all the messages defined by the OSPS so far were used. This work enables the APM to communicate with OSPS-compliant entities (MES, robots) through the RAMP IoT Platform. Technically, this integration was accomplished by implementing the RESTful API defined by the FIWARE Orion Context Broker in the APM.

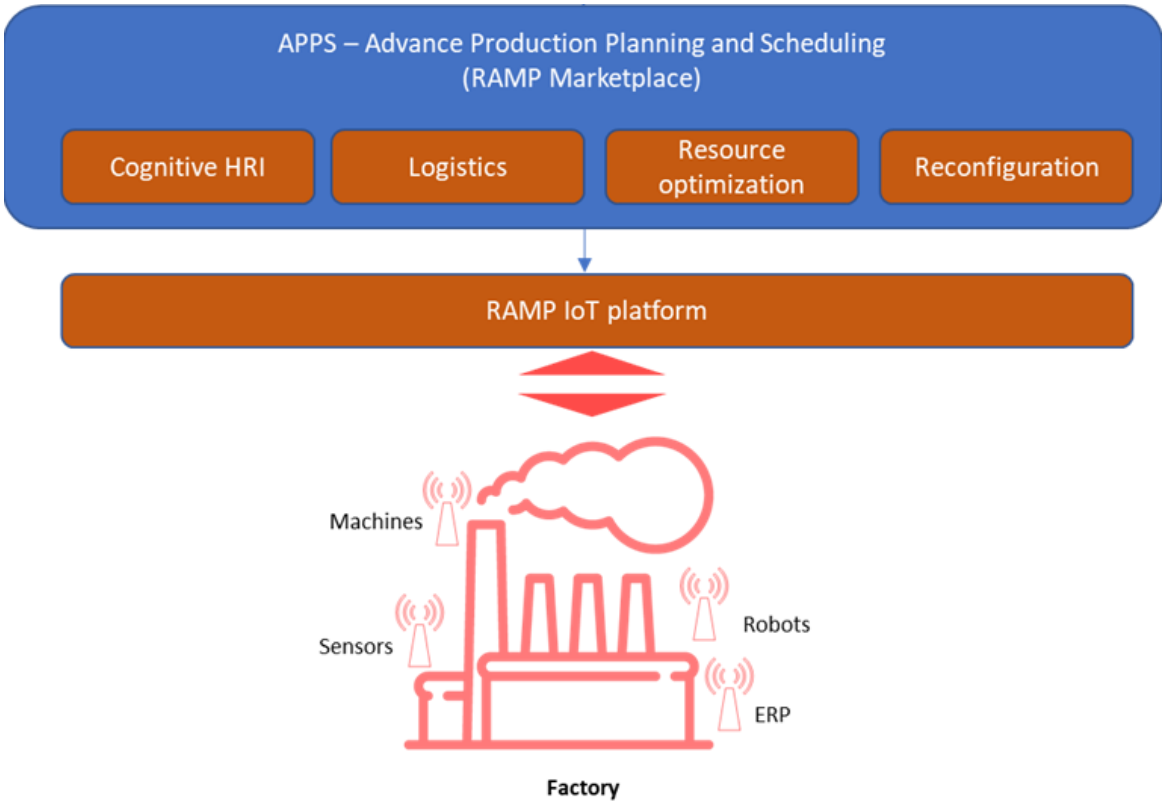


Figure 3 – Relationship between APPS, RAMP IoT Platform and devices in the factory´s shop floor

Figure 3 shows the importance of the RAMP IoT Platform in the integration of APPS and the devices available on the shop floor of a factory. This platform comprehends the ORION Context Broker and all the connectors/adaptors necessary to connect the devices in the factory with the elements within the APPS and also constitutes the instrument to connect the APPS components among themselves. During the first year of the Better Factory, the integration of the APM in the APPS (reported in the WP4 deliverables) was planned in the following two use-case packages:

- Production reconfiguration – Major component in this package is the MPMS (Manufacturing Process Management System), responsible for defining the sequence of production tasks to be achieved in a given manufacturing or logistic area. By using this component, a (human) Production Manager can specify the manufacturing/logistic tasks to be accomplished, their order, and their assignment to production resources, which include human operators and equipment. By enacting the process, tasks are signaled to human operators so that they execute the corresponding actions at the proper time and have access to the right information. In the case of equipment, the MPMS allows the implementation of an API (Application Programming Interface) in order to request the execution of an action from production equipment. In the case of robotic manipulators, the APM implements this interface, thus enabling robots to participate in the execution of certain manufacturing or logistic tasks (e.g. transporting work-in-progress materials between work stations).

  A subgroup of the OSPS messages implemented by the APM were identified and adapted to MPMS:

  - OSPS-APM-ManufacturingTasksDefReq - allows the APM to request the MPMS information about the type of tasks robots will be involved with;
  - OSPS-MES-ManufacturingTasksDefResp – response from the MPMS for the request defined above;
  - OSPS-APM-RobotProfile – information provided by the APM, taken from the digital representation of the physical area, identifying the profile of the available robots;
  - OSPS-MES-ManufacturingTask – message sent by the MPMS to the APM requesting the execution of a given task:
  - OSPS-APM-ManufacturingTaskStatus – message periodically sent by the APM to the MPMS stating the current state of execution of a given task, including its conclusion.

  Communication between the MPMS and the APM is supported by the RAMP IoT Platform.

- Logistics automation and optimization package –The component comprises several elements such as a real-time location system, a temporal heatmap of human occupancy and person detection & tracking, an agent optimization and a Logistics Library. The Logistics Library is an IoT platform that exploits the IoT paradigm to enhance communication among the different elements of the shop floor in order to create a flexible and responsive logistic system. In the case of AGVs, an integration was developed with the APM, in order to enable the Digital Twin Designer to generate digital artefacts needed by the Logistics Library (OPIL) solution and to show the dynamics of the AGVs in the digital representation by processing real time events created by the Logistics Library related to the movement the AGVs (details are provided in chapter 0 “

- Integration with robotic agents (via OPIL))".

  Communication between the Logistics Library (and the managed AGVs) and the APM is achieved via the RAMP IoT Platform.

As designed in the APPS architecture (see deliverable D4.2 "APPS architecture"), the Graphical User Interface of the APM has been used within the RAMP Marketplace co-creation space (section 'Projects', see also deliverable D2.2 "SME and artists co-creation space 1.0").

6 Integration with robotic agents (via OPIL)

The Open Platform for Innovations in Logistics (OPIL) was the solution adopted in the Better Factory project to operate logistics robots (e.g. AGVs) in a manufacturing environment. However, this solution requires the programmer to create three files describing the physical layout where the robots are supposed to navigate and operate. A list of the major physical objects present in the area with their locations and sizes should also be provided. The APM Tool enables the generation of these digital artefacts after the 3D model of the corresponding physical area, thus freeing the programmer from having to do it in a manual way, offering him/her instead the opportunity to benefit from the Tool's main modelling features. Furthermore, the physical characteristics and state (current position and orientation) of the multiple robotic agents operating within a robotic fleet can be sent to the Tool, through the RAMP IoT environment, allowing the APM to create a graphical representation of each agent and use it to show their navigation within the 3D visualization of the Model.

6.1 OPIL architecture overview

OPIL is a suite of applications for rapid development of complete logistics solutions targeting the logistics sector in small-scale Industry 4.0 contexts (such as those of manufacturing SMEs). It also provides connectivity tools to factory floor equipment such as mobile robots and AGVs (among many other options). OPIL component applications are logically grouped into the following three-layered architecture (figure below):

- IoT Nodes Layer (1) - all components that interact with the physical world (via robotic agents, sensors, or human operators);
- Cyber Physical Middleware Layer (2) - set of data brokers supporting communications between components belonging to distinct OPIL architecture layers as well as with external applications and the OPIL stack;
- Software Systems Layer (3) - set of high-level application components that abstract interactions with Layer 1 components from the user and allow for complex behaviour.

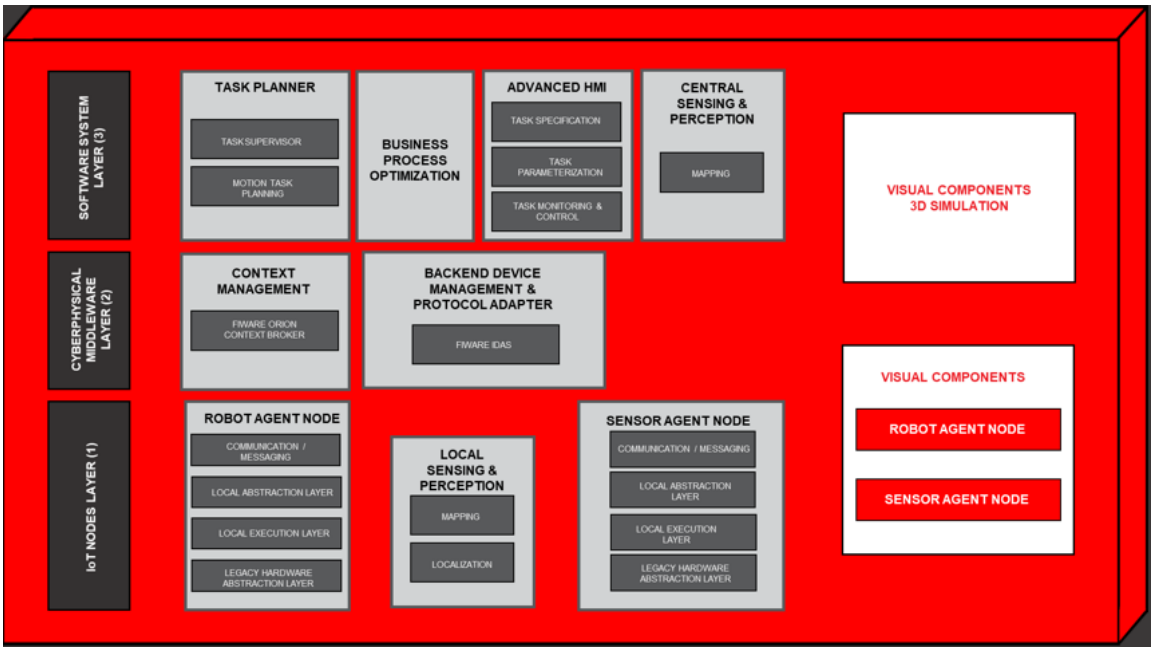


Figure 4 – OPIL architecture

6.2 RAN and FIWARE

To actually communicate with robotic agents the Robot Agent Node (RAN) component was used. RAN is an OPIL Layer 1 component that works as an interface between the robot hardware (running ROS) and the FIWARE

Orion Context Broker (OCB), a Layer FIWARE's Publish/Subscribe Context Broker GE Open Specification 2 component.

Robot Operating System (ROS) is an open source set of software libraries and tools targeting robot applications. It is currently the de facto software development tool in the robotics industry. ROS applications consist of independent ROS nodes that communicate with each other following a publisher-subscriber paradigm. This communication is done by exchanging ROS messages in three ways (pub-sub, services and actions) through ROS topics.

FIWARE is also an open source framework that consists of multiple components applications, targeting the Internet of Things (IoT). One of its main components is the Orion Context Broker. It collects contextualized data from diverse sources (publishers) such as IoT devices and software applications and then manages that data. Contextualized data consists of entities and its attributes.

RAN provides both robot navigation and bilateral translation between FIWARE entities and ROS messages. This conversion is done with the help of FIROS.

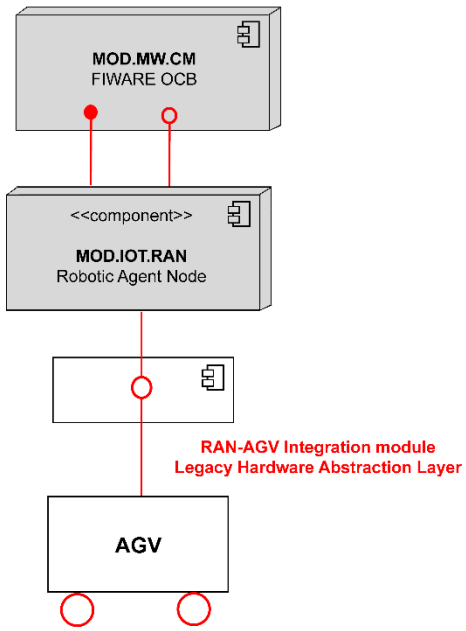


Figure 5 – OPIL connection with an AGV

To retrieve information about robotic agents the APM communicates with an OCB instance and queries for all relevant data for the present use case. All data has its origin in ROS-based robotic agents that interface with RAN and is then translated via FIROS and sent to OCB.

6.2.1 Messages Exchanged

Multiple data messages are produced and consumed by RAN via the OCB.

However, to generate a Digital Twin representation of a given robotic agent, it suffices to know its current position and orientation as well as its bounding volume dimensions. Therefore, only a subset of all exchanged messages is actually useful.

In the following subsections, for simplicity reasons, only the structure of the ROS messages is shown. It should be noted that FIWARE-compatible translations using FIROS maintain the same exact structure (only the overall data format changes).

6.2.2 Robot position and orientation

A robotic agent's pose can be obtained via the current_motion exchange that contains information about the current position, orientation and movement velocity of a robotic agent.

It corresponds to ROS messages of type mars_agent_physical_robot_msgs/Motion, having the following structure:

```
geometry_msgs/PoseStamped current_position

geometry_msgs/Twist current_velocity
```

Only the contents of field current_position are required. It contains the coordinates of the robot (of it's center of mass) relative to the conventionalized origin of the world in which it is operating as well as it's orientation also relative to said origin.

6.2.3 Robot bounding volume

To assemble the bounding volume of a given robotic agent the exchange robot_description is used. It contains information regarding an agent's physical properties (weight, bounding volume, etc.) as well as associated metadata (maximum payload, current battery percentage, etc.).

It corresponds to ROS messages of type mars_agent_physical_robot_msgs/RobotAgentProperties, having the following structure:

```
mars_common_msgs/Id robot_id
VehicleType type
geometry_msgs/PolygonStamped footprint
float32 min_height
float32 max_height
float32 payload
float32 max_pos_x_vel
float32 max_neg_x_vel
float32 max_pos_x_acc
float32 max_neg_x_acc
float32 max_pos_y_vel
float32 max_neg_y_vel
float32 max_pos_y_acc
float32 max_neg_y_acc
float32 max_pos_ang_vel
float32 max_neg_ang_vel
float32 max_pos_ang_acc
float32 max_neg_ang_acc
float32 velocity_control_sensitivity
float32 min_turning_radius
float32 batt_capacity
float32 batt_max_voltage
float32 weight
string vendor
RobotAction[] action_capability
```

To construct a bounding volume, the height of the robot and the point coordinates of it's base projection are required. The height of a robotic agent value can be extracted directly from the field max_height. However, the point coordinates of the robot's base must be indirectly extracted from the field footprint, structured as follows:

```
Header header

Polygon polygon
```

The inner field polygon contains the required point coordinates.

6.2.4 APM's configuration

The real-time visualization of of the robots controlled by OPIL may be achieved in the 3D window of the APM. For this purpose, the APM must be installed in the same computational environment where the OPIL server is running. A binary version of the APM has to be downloaded from the Better Factory Github repository (https://github.com/ramp-eu/Advanced_Plant_Model) and installed in a docker-based environment (as instructed by the Github repository).

By default, the APM subscribes the following entities on the ORION CB (Context Broker) of the RAMP IoT Platform:

- id: map type: ROBOT
- id: robot.* type: ROBOT

where 'robot.*' is a pattern denoting any ROBOT message with a name starting with 'robot' such as 'robot_opil_v2'.

In the context of OPIL integration, the APM has the following behavior:

- OPIL Messages are processed in the context of the 'OpilArea' physical area. This name is pre-defined in the APM. When generating the digital artifacts for OPIL (part 1 of this tutorial) you should name the physical area as 'OpilArea'.
- The 'map' message coming from the ORION CB is processed by the APM but the Tool doesn't do anything with the contents of this message.
- Messages from the robots are processed and the APM expects two JSON fields to be in the message: **current_motion** and **robot_description**. These are used to update the localization of the robot in the 3D area and to set the geometric dimensions of the robot.
- The APM instantiates a robot on the first message coming from a robot through the Orion CB. The robot type with the same name is used in the instantiation of the robot in the 3D Model.

7 User Manual

This section describes the main features of the Digital Twin Designer (the Tool), taking the perspective of the final User. Thus, this section is the User Manual of the tool. A set of screenshots support this manual so that the User always sees the concrete elements he/she interacts with in the context of each main feature being explained. In the text, the term Interface is used to designate the User Interface of the Tool.

7.1 The Login process

Usage of the Tool requires the User to go through an authentication process, through which the User has to supply a username and corresponding password. As the Tool is integrated with the RAMP Marketplace, while still being an autonomous system, running in an independent way, this authentication process is done by the RAMP Marketplace by following the OAuth2 protocol (https://oauth.net/2/), the industry-standard protocol for authorization. The following steps guide the User:

1. The Tool shows the screen below, where the User presses the "RAMP…." button.

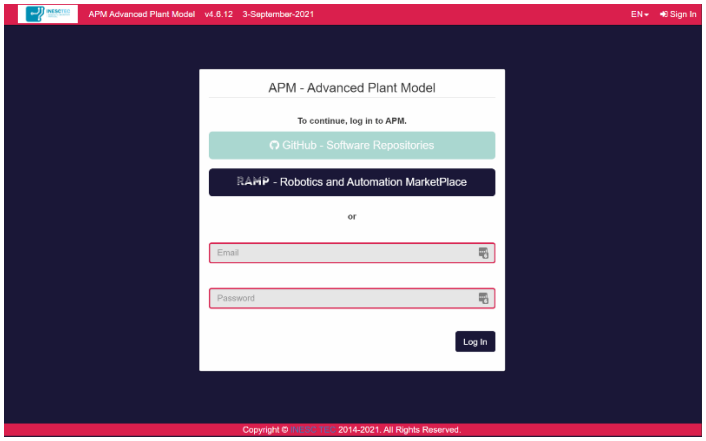


Figure 6 – Login process: 1st step

2. In the first access to the Tool, a screen is presented asking the User to authorize the Tool to access his/her account on the RAMP Marketplace.
3. Subsequently, the RAMP Marketplace presents the screen below (left), asking the User to enter his/her user name and password.
4. Another window is shown by the RAMP Marketplace (below, on the right), asking the User to authorize the RAMP to access his/her account.

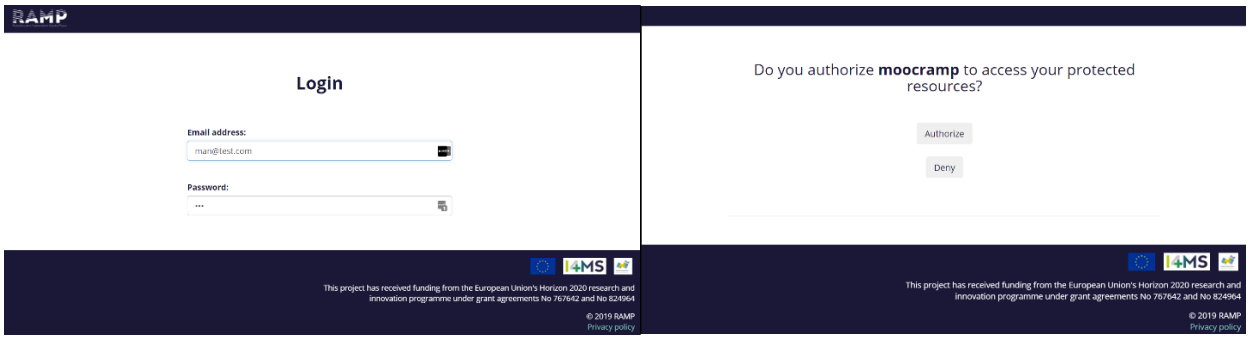


Figure 7 – Login process: 2nd (left) and 3rd (right) steps

In the end (after the User has provided all the right information), the login process is completed and control is given to the Tool. The Tool's interface is shown (Figure 8), allowing the User to start using the Digital Twin Designer.

7.2 Organization of the user interface

After a successful login process, the Tool presents its user interface as shown below.

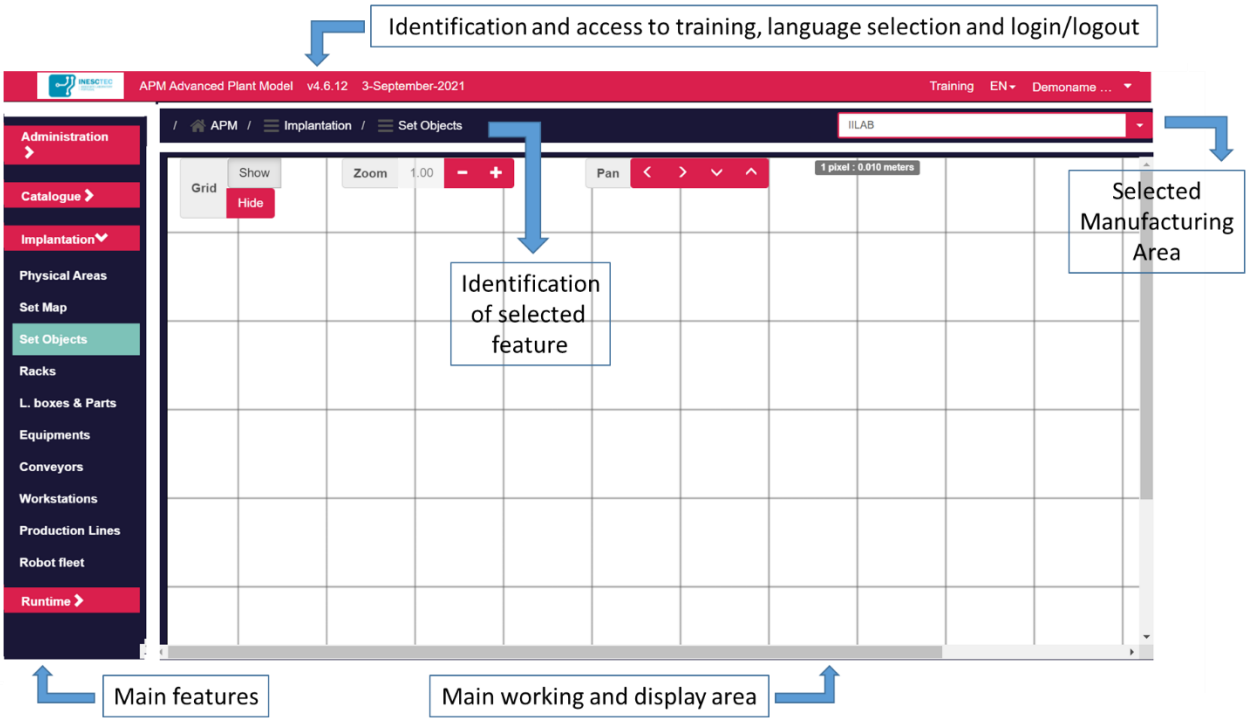


Figure 8 – User Interface: main working areas

The Interface is organized in four areas:

- The top area identifies the Tool (name and version) and allows the User to access a training area (see chapter 0 “

- How to"), to change the language used by the Tool (at present stage English and Portuguese are the supported languages) and to exit the Tool.
- The left area provides access to the available application features (Administration, Catalogue, Implantation and Runtime) that are then presented in the central area of the Interface.
- The central area is the area where most information is presented and where the value-adding interactivity with the User takes place.
- Between the top and central areas, on the left, a "breadcrumb" is displayed identifying the feature of the application that is active and its navigation hierarchy ('APM / Implantation / Set Objects' in the above picture). On the right side, a drop-down list lets the User select the physical area (e.g. a logistics or assembly area) he/she is working on. This is VERY important. By opening this drop-down list, all the known physical areas are shown, letting the User select the one which he/she will start to work with ("IILAB" in the picture above). After this selection, the implantation and Runtime features are dependent on the selected physical area.

7.3 The Administration area

This application feature identifies which Users have already entered into the Tool (successfully concluded the login process). As the Tool is integrated with the RAMP Marketplace, any User in the RAMP Marketplace is associated with an organization. By default, all the users associated with a company can use the Tool.

As shown in the picture below, the Tool knows two users ('Demoname' and 'Providername'), that are associated with the 'test.com' organization. By selecting one user (e.g. 'Demoname'), the Interface allows one to update the picture that will visually identify the User in the Interface. The remaining options, 'Edit Profile' … have no effect when the Tool is integrated in the RAMP Marketplace.

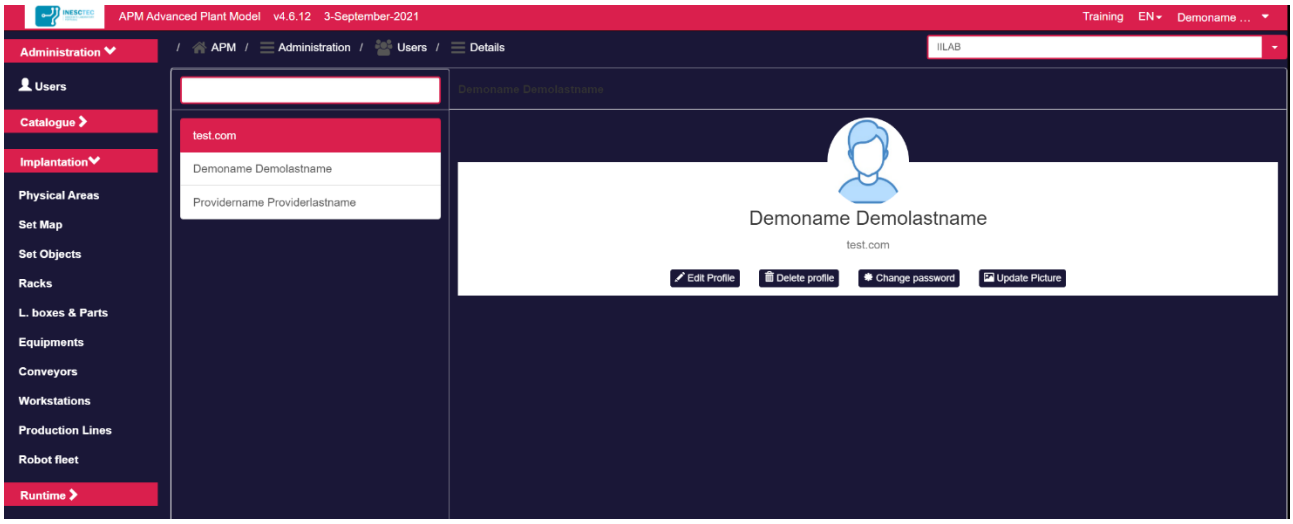


Figure 9 – Administration feature

7.4 The Catalogue

The Catalogue is the application feature responsible for keeping a list of all the known 3D models. Depending on the final goal of the User, each significant object present in a physical area (e.g. a workstation) should have a correspondent 3D model. The Catalogue is the feature which allows the User to create, change or remove the models associated with each type of object. The purpose of the Catalogue is to enable the user to build models of a given physical area by "instantiating" and "implanting" the object models on the digital representation of the physical area.

Presently, the application supports the following types of objects: Racks, Large Boxes, Small Boxes, Kits, Workstations, Conveyors, Equipments, Robots, Production Lines, Parts and FinalProducts.

7.4.1 Listing the objects

By selecting an object type on the left area of the Interface (see picture below where 'Equipments' is selected), a list of all known models is shown, presenting the name and the geometrical dimension of the object's volume.

On top of the list, a button "+ New equipment" enables the creation of a new object type (described later in this chapter).

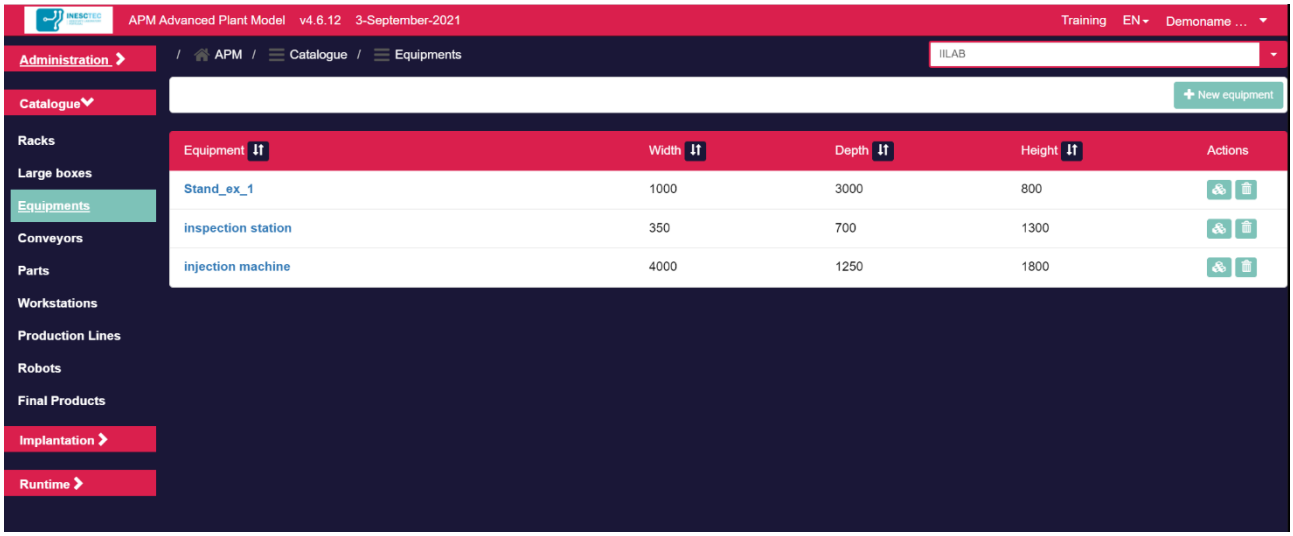


Figure 10 – Catalogue: List of object types

The two buttons on the right of each row (picture above) allow the User to remove a model or to visualize and edit its 3D model. Pressing the latter causes the Interface to access the 3D model of the selected object (see picture below). User is now able to see the details of the model by using the mouse in the image:

- Pressing the left button and dragging the mouse allows one to orbit around the object's image;
- Rolling the central button allows one to zoom in or zoom out the image;
- Pressing the right button and dragging the mouse allows one to pan the object's image.

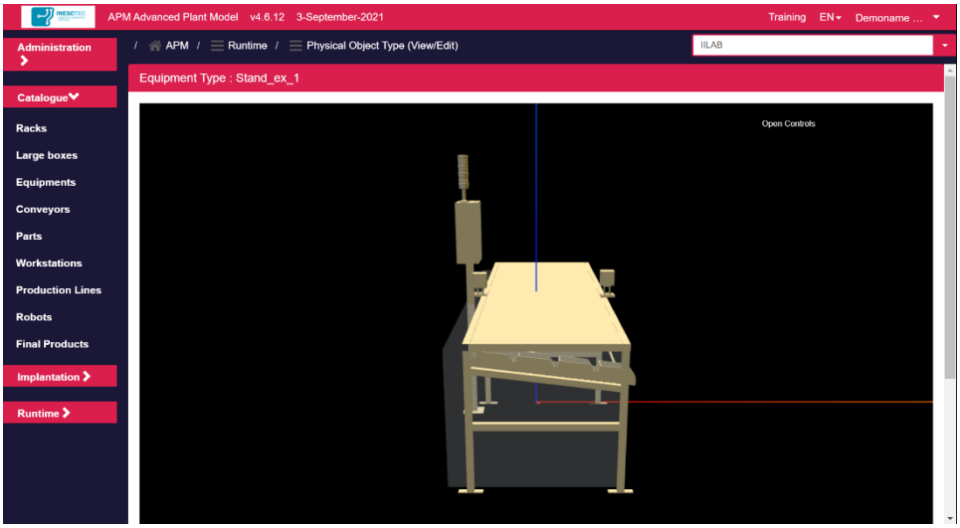


Figure 11 - Catalogue: Access to the 3D Model of an object type

7.4.2 Adjusting the CAD model to the object's bounding volume

By clicking on the top right button 'Open Controls', a new window is presented (see picture below), letting the User change the position of the 3D CAD model in the object's bounding volume. Please note the following:

- Each and every object created in the Catalogue has a bounding volume with the external dimensions provided by the User during model creation (with, depth and height).
- Optionally, a CAD model may be associated with an object. The following formats are supported: STEP, STL, PLY, URDF. After assigning a CAD model to an object, its position within the bounding box can be adjusted if needed.

The adjustment of the CAD model is accomplished by moving its geometry within the bounding volume:

- The 'red axis', 'green axis' and 'blue axis' slider widgets on the 'large displacement' zone, cause the geometry to move in the three X, Y, Z dimensions;
- The widgets below with the very same names but under the 'fine-tune displacement' zone, also allow one to adjust the position of the 3D geometry within its bounding volume but with greater precision.
- The 'Rotation' widgets allow the CAD image to rotate around its X, Y, Z axis.

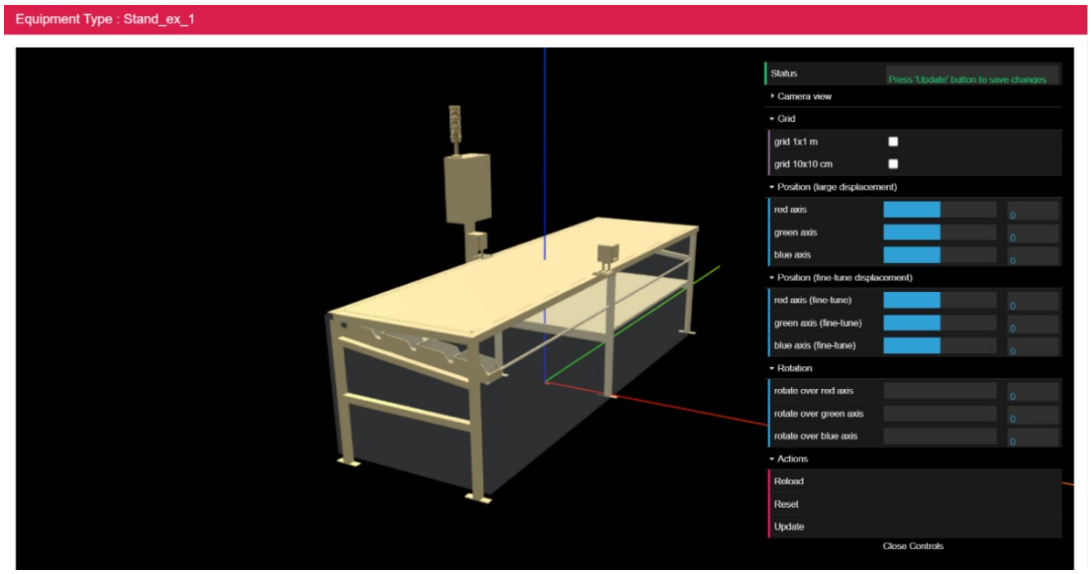


Figure 12 – Catalogue: Access to the 3D model of an object

The following picture shows the same object but the CAD model is completely separated from the bounding volume of the object. This situation must be avoided because the bounding volume is the concept that will enable the User to locate an instance of the object in the proper place within the model of a physical area.

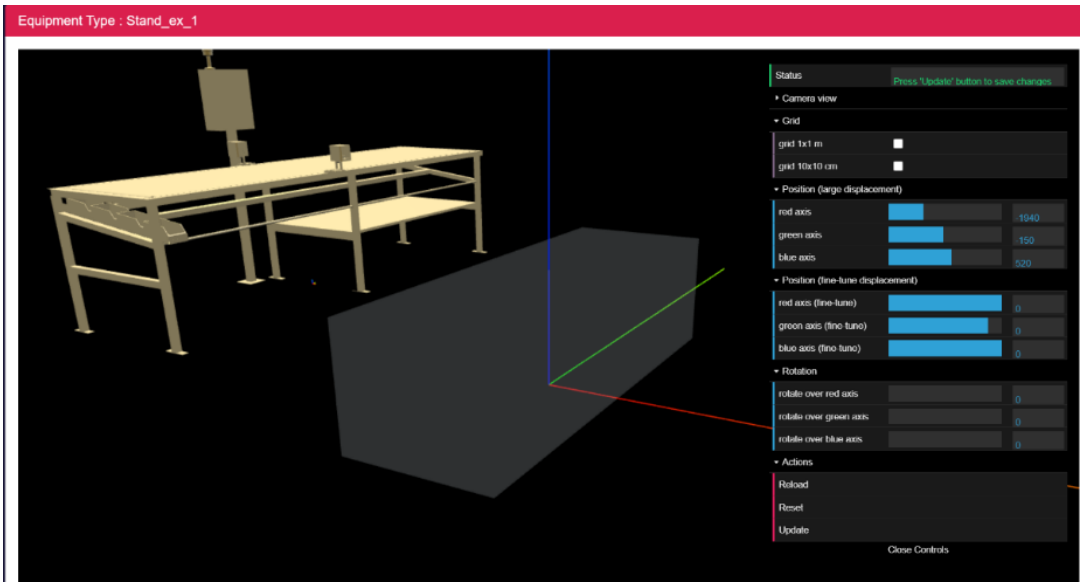


Figure 13 - Catalogue: separation between the CAD model and the bounding volume of an object

7.4.3 Creating a new object type

As shown on Figure 10, on top of the list identifying the different models of a selected object category, a button "+ New *(Object Type)"* is present, enabling the User to create a new object type.

For all the object categories, the creation of a new object model, comprises the following steps:

1. Identification of the new object model, by supplying an identifier and the dimensions of the object's bounding volume, that is, the dimensions of the volume that encompasses the physical elements of the object.

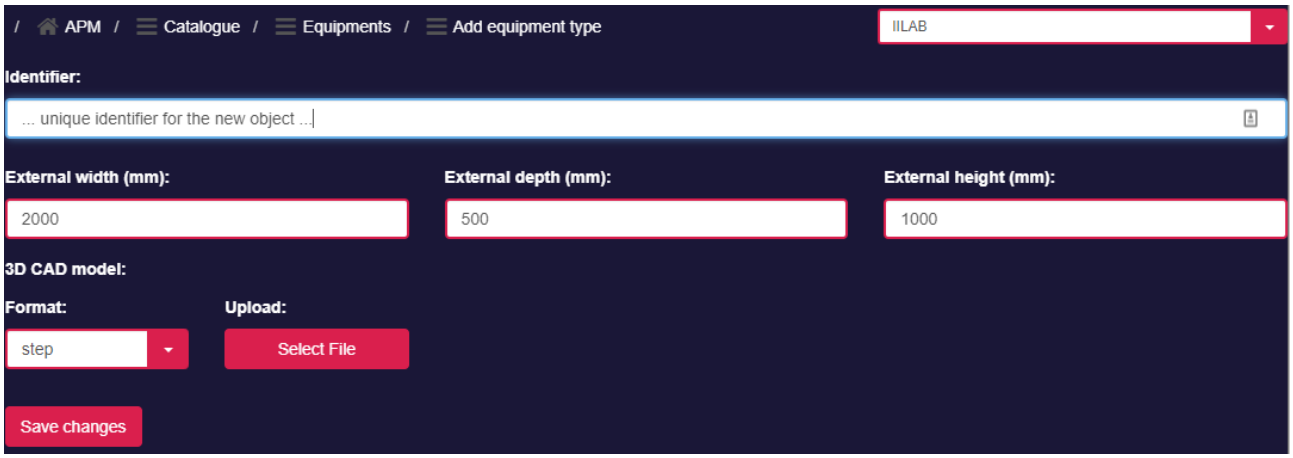


Figure 14 - Catalogue: Identification of new object

2. Uploading of the CAD model that corresponds to the new object. The CAD model is uploaded by the User and may be a STEP, STL, PLY or URDF file or set of files. This step is optional but recommended. As shown below, the button 'Select File' triggers the selection of the files. A new field is then presented, to enable the user to specify the scale conversion (from meters to millimetres).

Figure 15 - Catalogue: Upload of CAD model

3. Identification of the internal geometry of the new object. This step is mandatory for logistics racks and Large boxes (logistics pallets). In both cases, the Tool requires the User to specify the number of levels (rack) or layers (pallet) in the object and their physical dimensions. Additionally, information about the following characteristics are requested by the User:

   - In a logistics rack - The physical dimensions and positioning of each level. Levels may be horizontally and/or vertical displaced and each level can also be subdivided into cells. Once instantiated (see section 7.5) logistics racks can support on each compartment small boxes containing physical elements (parts).

- In a logistics pallet - The physical dimension of each layer and the number of cells planned to hold one physical element (part).

The following pictures show the interfaces used to collect this information from the User.

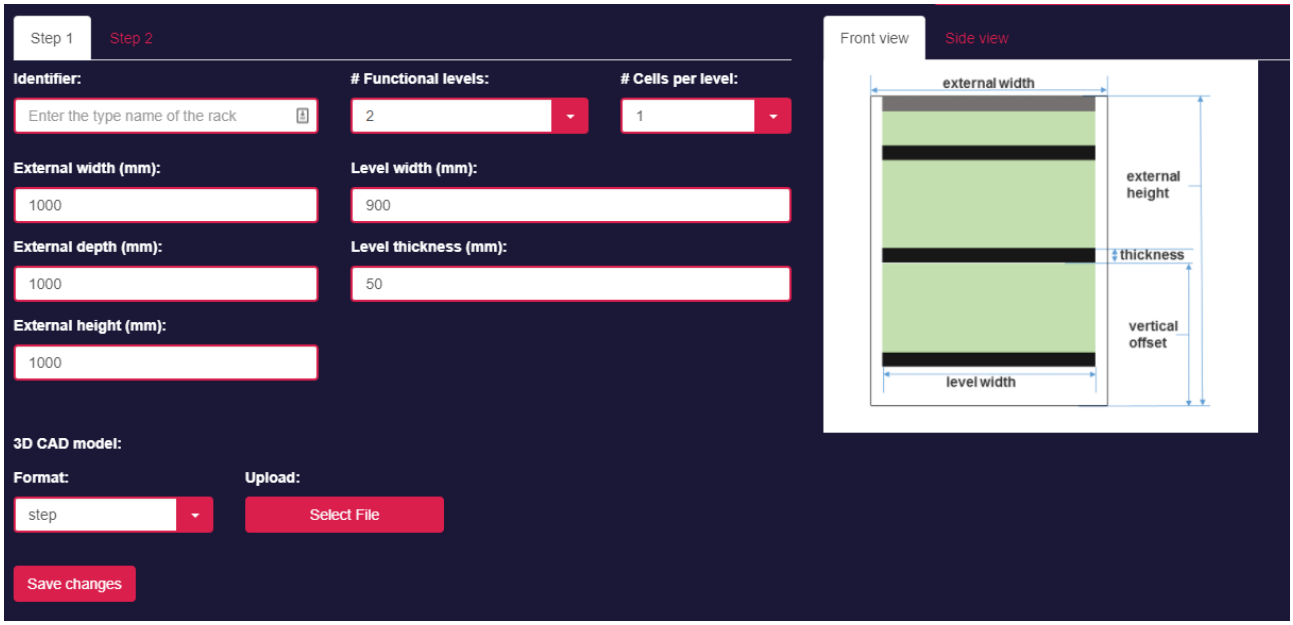


Figure 16 - Catalogue: Internal geometry of a Rack (part 1)

Figure 17 - Catalogue: Internal geometry of a Rack (part 2)

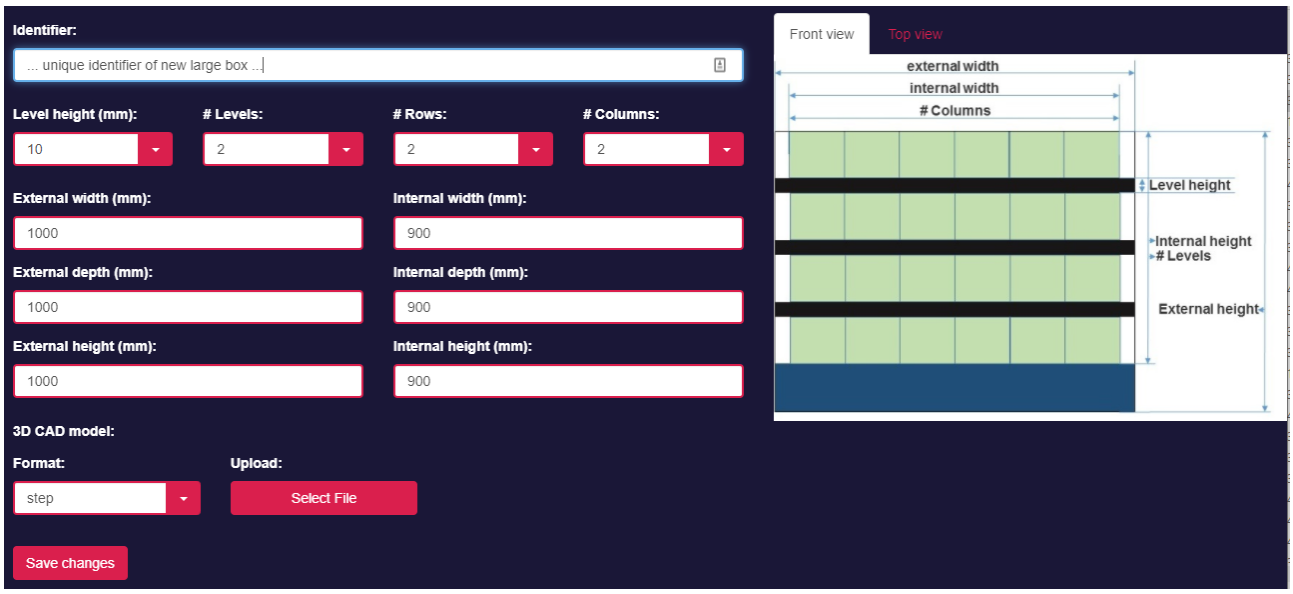


Figure 18 - Catalogue: Internal geometry of a Pallet

7.5 Implantation

The implantation feature aims to enable the User to build the digital representation (model) of a given physical area, be it a logistics area, assembly line or any other manufacturing area. The main elements used to build the model are the Catalogue and a Map of the area. The Catalogue contains the models of the objects that may be used in the creation of the model. The Map of the area constitutes the instrument that will enable the User to “implant” objects and their proper locations. Naturally, the Map must represent the layout of the area one is targeting to model.

The creation of a given physical area model comprises the following steps:

1. Specification of a Map to represent the physical area to model
2. Implantation of object instances in the Map
3. Checking and validating the entire model by visualizing it in 3D

7.5.1 Specifying the Map

The Map is the first instrument to use in order to build the digital representation of a given physical area. The Map must have a dimension (in meters) and may have a 2D image that graphically identifies the objects that are presented in the physical area. By default, if a 2D image is not supplied, the Tool represents the map in the screen as a grid, as shown in the picture below.

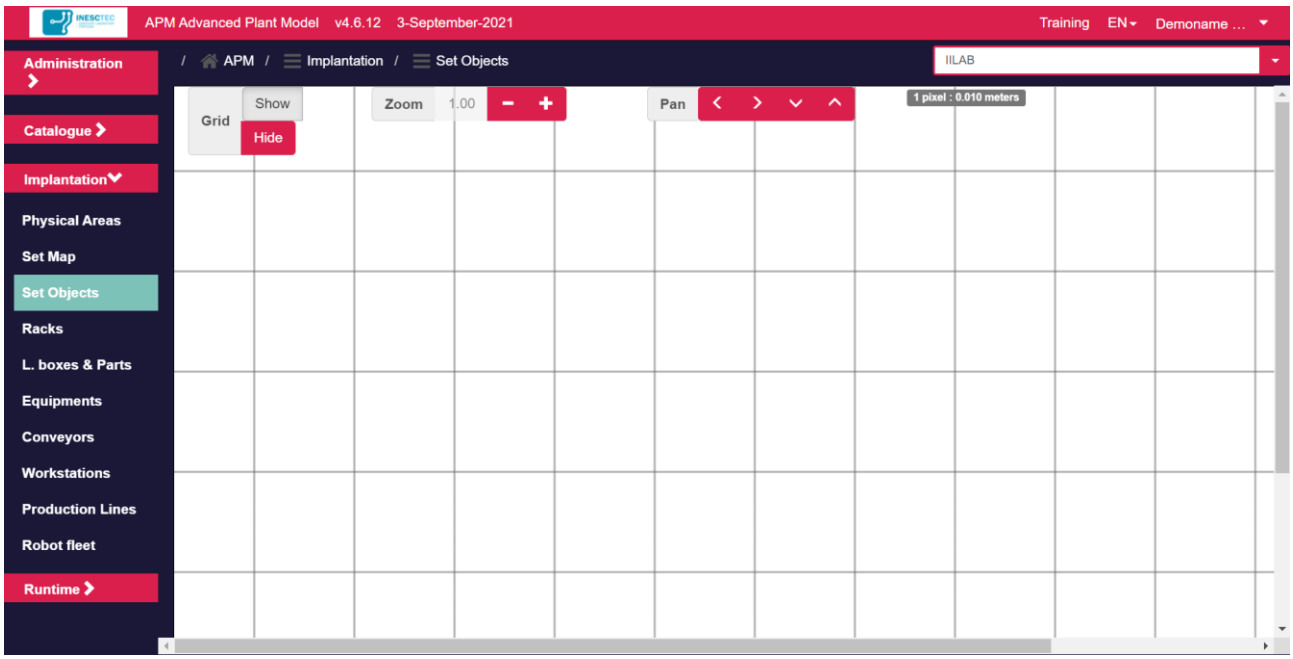


Figure 19 – Implantation, 'Set Objects' screen

The specification of the 2D image, reflecting the layout of the area, must me provided on the first step in the creation of the model, by following these steps:

1. On the Implantation area, select the 'Physical Areas' feature. All the physical areas created so far are listed in the central area of the Interface.

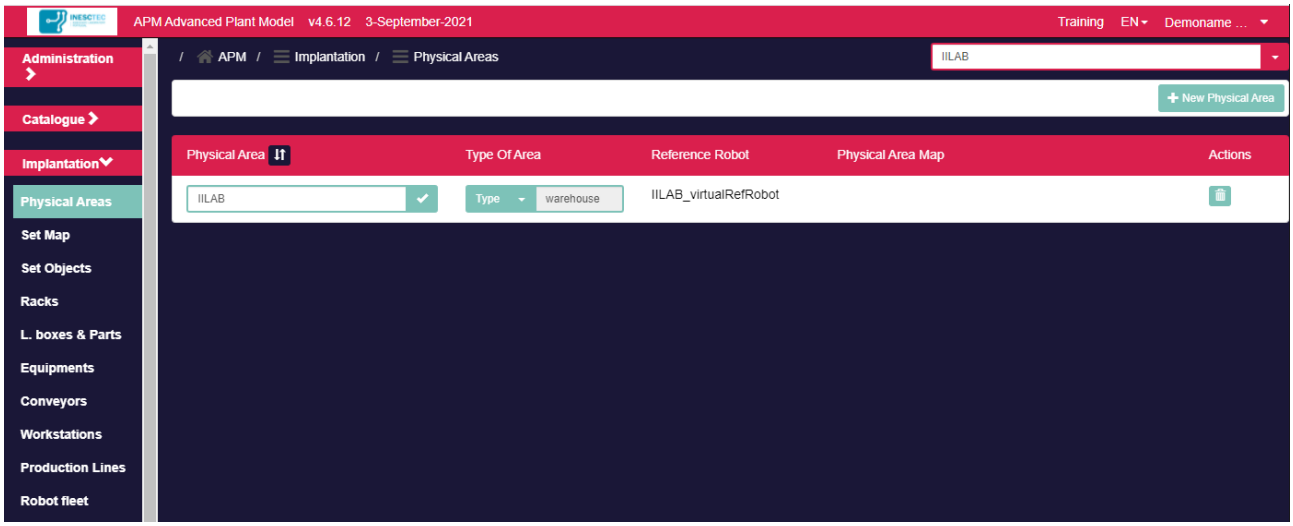


Figure 20 – Implantation, 'Physical Areas' screen

2. Press the button 'New Physical Area' (top right zone of picture above) to open the screen shown below. User is requested to name the area, to supply the physical dimensions of the area and to optionally provide a 2D image, uploading the image from his/her own computer.

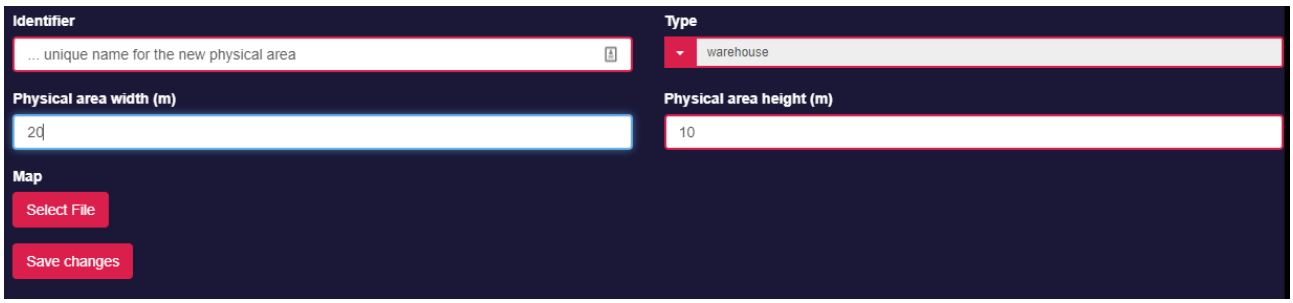


Figure 21 – Implantation: Initial creation of a physical real

The following picture shows the Map that corresponds to the area 'assembly_area_1', for which a 2D image was supplied as map. When supplying the Map, the User has to identify the scale of the image (how many meters are represented by each pixel in the image map).

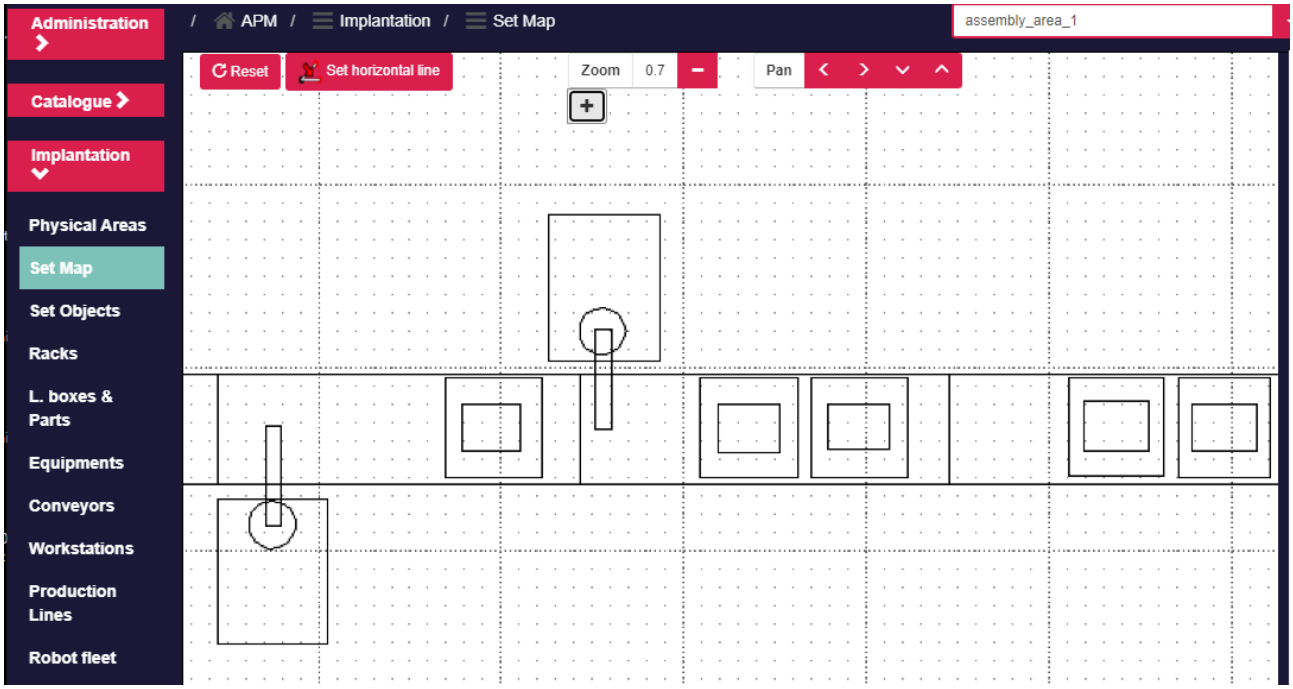


Figure 22 – Implantation: 'Set Map' screen

In the case the map image has not the same orientation as the screen used to visualize the map (top picture on the following Figure), the User can specify a horizontal line in the map by selecting two points in the image. This is done by selecting the "Set horizontal line" button, available on the top of the image. See the first picture below, showing a horizontally non-aligned image and the second picture that shows the very same image but aligned horizontally, after the specification of a horizontal line (by selection of two points in the image). The image shown on the second image below was generated by a mobile robot, that has navigated around in the physical area and analysed by laser scanning the area in order to detect opaque zones.

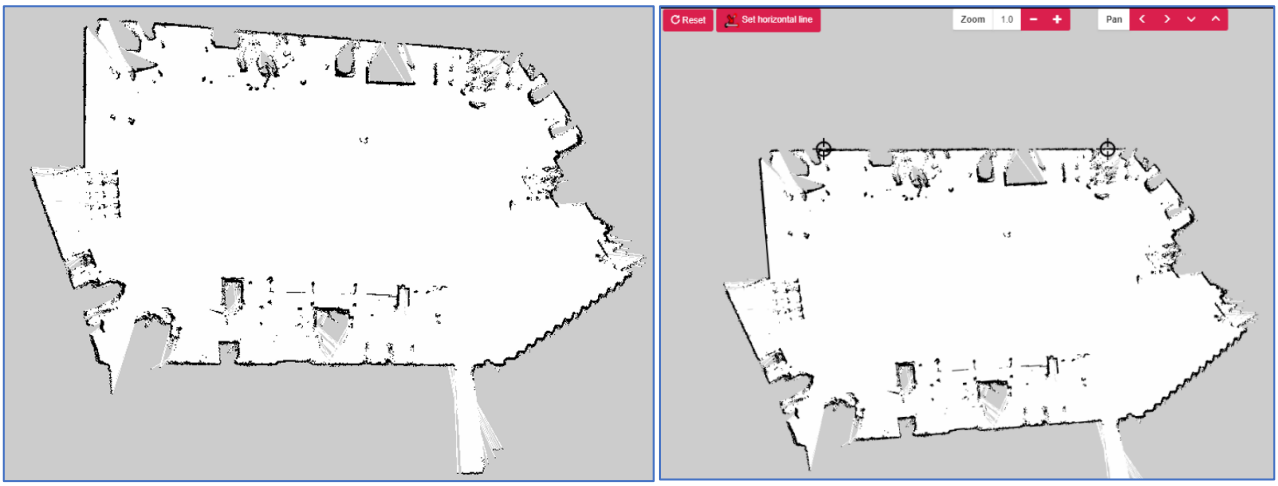


Figure 23 – Implantation: Map non-horizontally aligned (on the left) and horizontally aligned (on the right)

The visualization of the map may be adjusted by clicking the 'Zoom' and 'Pan' red buttons available on the top of the image.

The 'Reset' button resets the horizontal alignment of the image.

7.5.2 Implanting objects in the Map

The implantation of objects in the Map is done on the 'Set Objects' screen (see picture below).

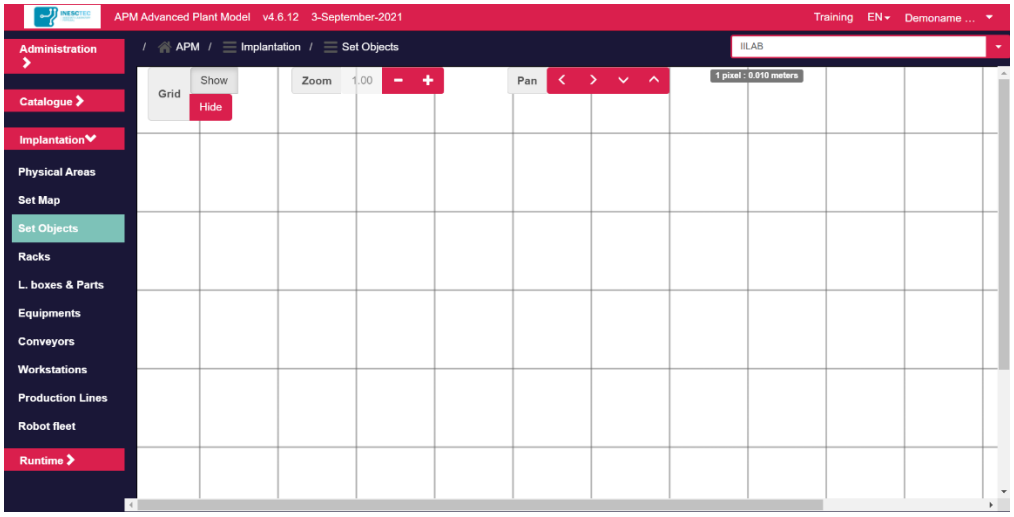


Figure 24 – Implantation: 'Set Objects' screen

After zooming and moving the image to obtain a proper representation of the area, the procedure is very simple. The right mouse button must be pressed and the Catalogue is presented, letting the User choose the type of object he/she intends to deploy (picture below).

Figure 25 – Implantation: selecting an object from the Catalogue

By selecting object types from the Catalogue, the Tool creates the corresponding instances and places them on the location where the right mouse button was pressed. A rectangle containing red arrows represents the external volume of the object instance. The red arrows specify the orientation of some objects where the front-face and back-face must be distinguished. The following picture shows three objects implanted in the map. In this scope, one can move each object instance by pressing and holding the left mouse button, and dragging it until the object reaches the intended location.

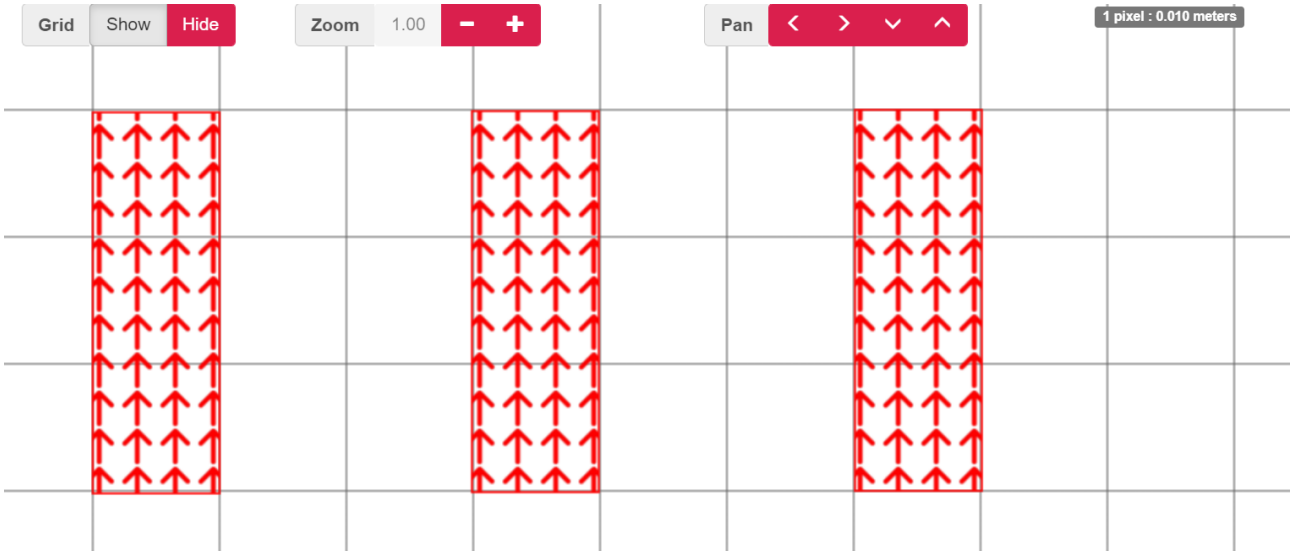


Figure 26 – Implantation: Populating the map with objects

When selecting an object by pressing the right mouse button, a pop-up menu is shown, presenting actions that can be performed on the selected object (e.g. cloning the object, renaming the object, rotating it or removing it from the map).

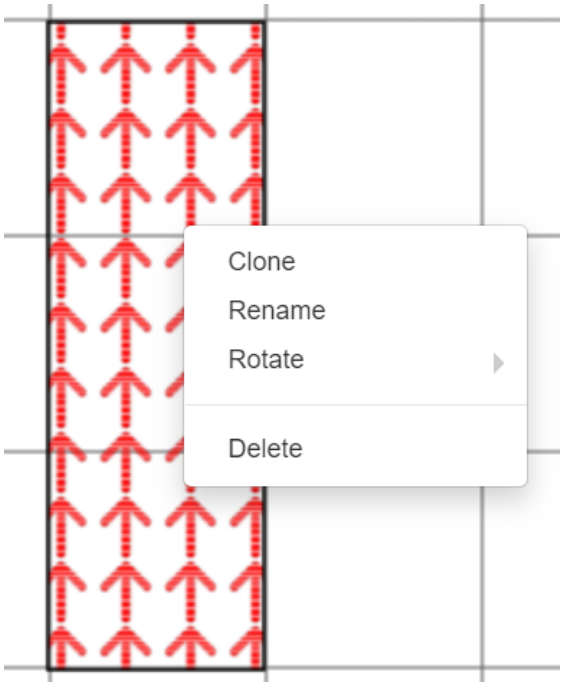


Figure 27 – Implantation: selecting an object to act on it

It is also possible to select several objects and align vertically/horizontally their representations, rotate them or remove all of them from the map (see next picture).

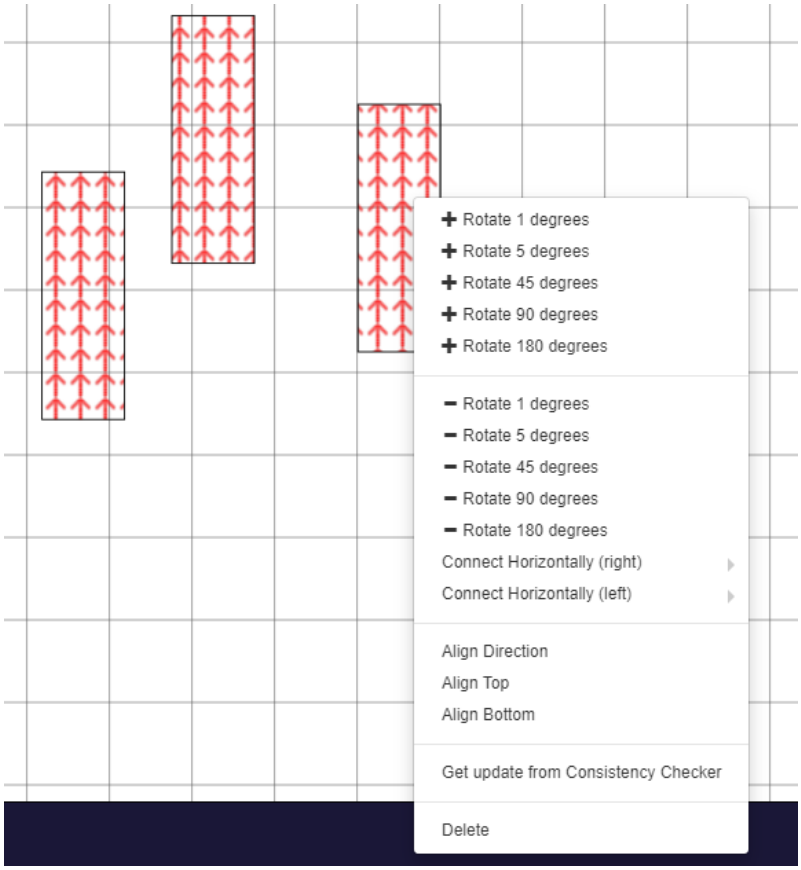


Figure 28 – Implantation: Selecting several objects in order to act on them

7.5.3 Validating the Model

The visual validation of the Model (the digital representation of a given physical area) is done by inspecting the three-dimensional model that one has built so far. This is achieved in the 'World Model' feature as shown below.

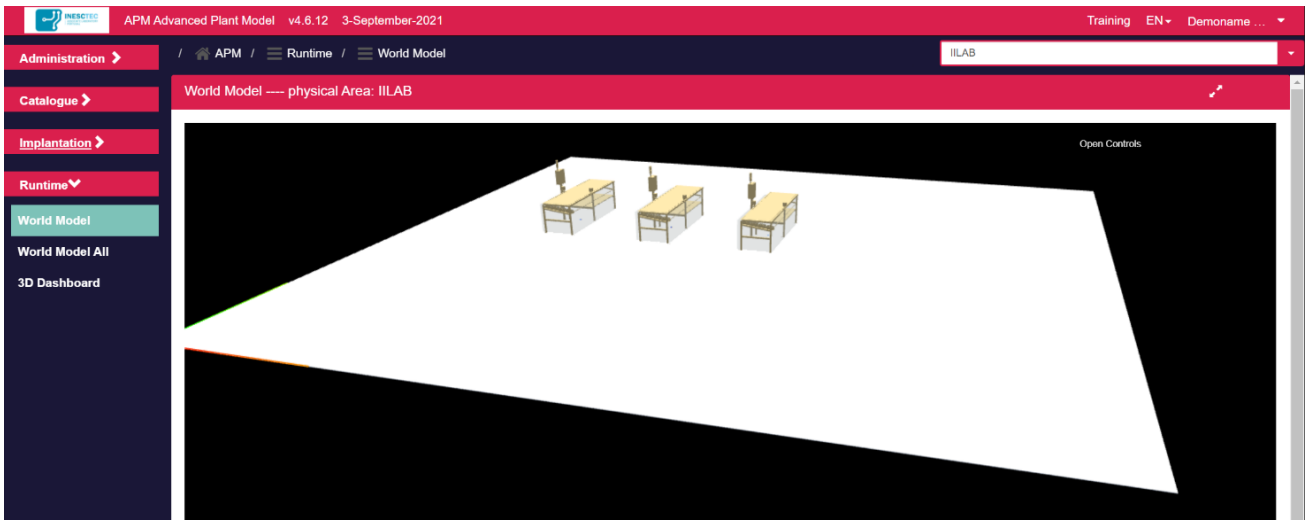


Figure 29 – World Model screen

The Interface allows the User to navigate in the 3D model, by zooming in and out, and orbiting around the objects. The mouse is used in the same way as used to visualize the 3D Model of a single object:

- Pressing the left button and dragging the mouse allows one to orbit around the object's image;
- Rolling the central button allows one to zoom in or zoom out the image;
- Pressing the right button and dragging the mouse allows one to pan the object's image.

7.6 Generating OPIL artifacts

The digital representation of a given manufacturing area created by the APM can be used to generate the digital artefacts needed by the OPIL solution:

- A 'png' file containing a bidimensional graphical image of the physical area (i.e. the map of the physical area);
- A 'yaml' file with a semantic description of the previous map (resolution, origin, …);
- An 'annotations.ini' file specifying all the the implanted objects in the map.

After having created the digital representation of a manufacturing area, one should go to the 'Set Objects' part of the user interface (section 7.5.2 "Implanting objects in the Map") and use the right mouse button to instruct the Tool to generate data for the OPIL solution. The first figure below shows the relationship between the 'set objects' screen and the three-dimensional visualization of the Model. The second figure below shows the generation of the OPIL artefacts.

"Annex A" identifies the OPIL artefacts.

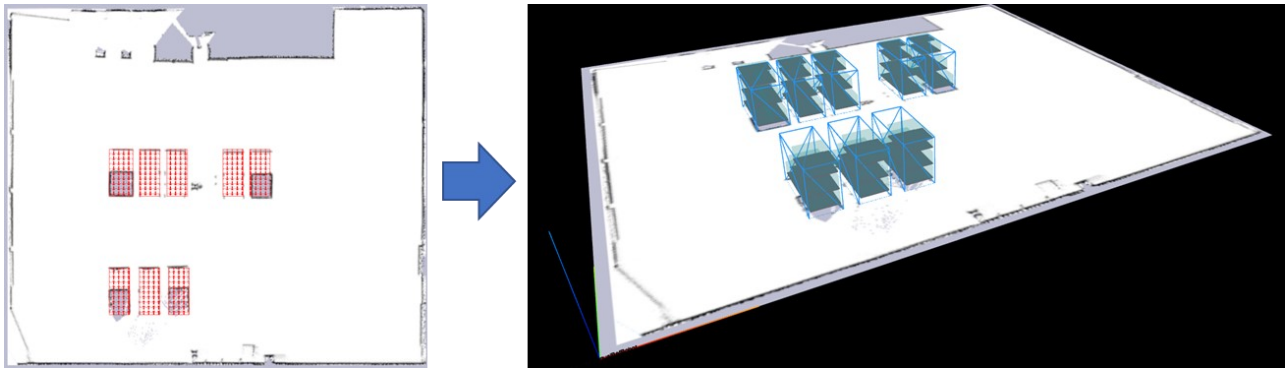


Figure 30 – 'Set Objects' screen and the corresponding World Model screen

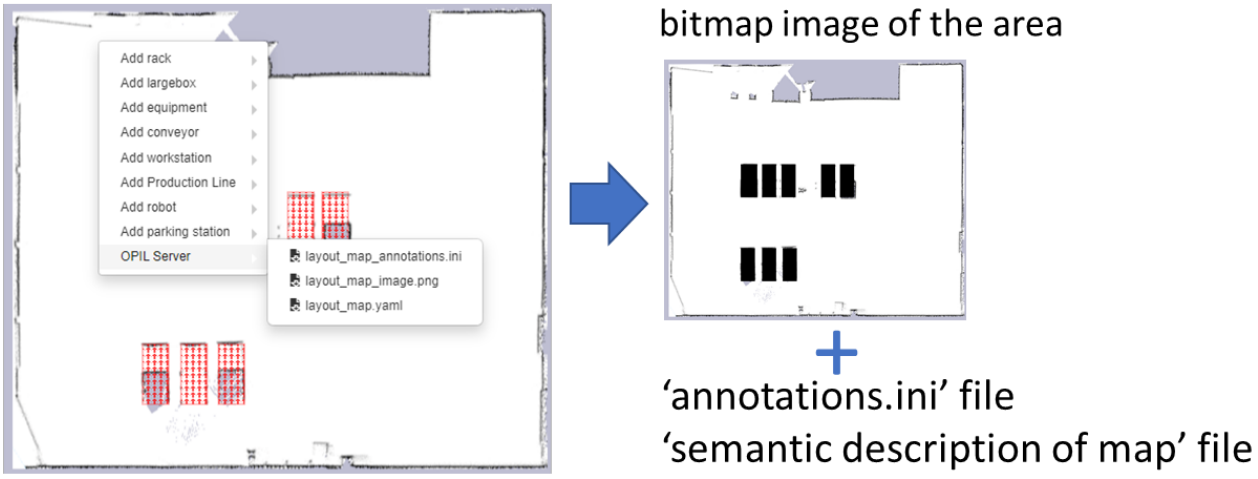


Figure 31 – Generation of OPIL artefacts

8 How to

This section provides nine use cases oriented to helping the User accomplish typical actions on the construction of a Model through the Digital Twin Designer (mentioned in the text as “The Tool”):

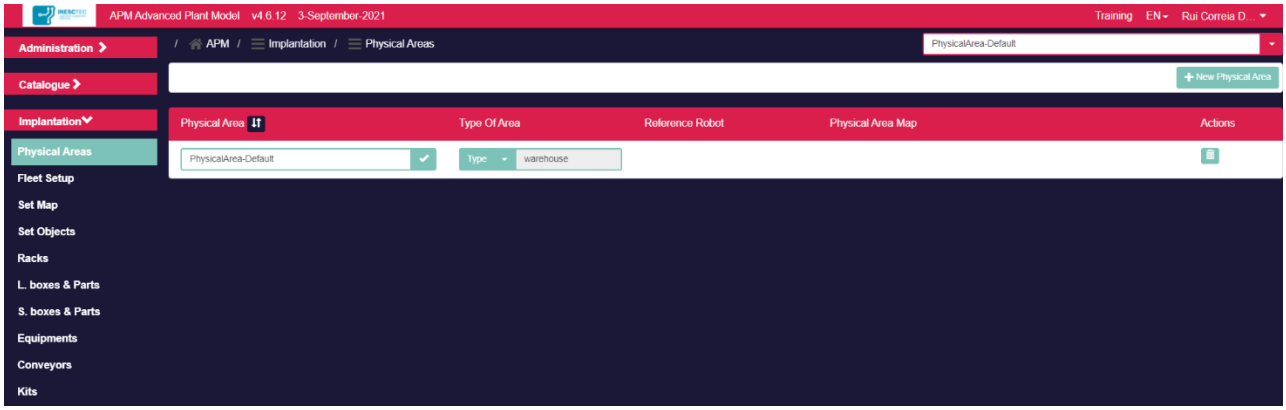
- How to create a physical area
- How to implant objects on a physical area
- How to create a physical area with a map
- How to add a new rack to the catalogue
- How to add a new rack to the catalogue with STEP
- How to add a new equipment to the catalogue
- How to add a new workstation to the catalog
- How to add a new production line to the catalog
- How to integrate the APM with the OPIL server

These use cases are directly provided by the Tool itself on the training area, which also gives the User access to examples of CAD models that are required to go through them.

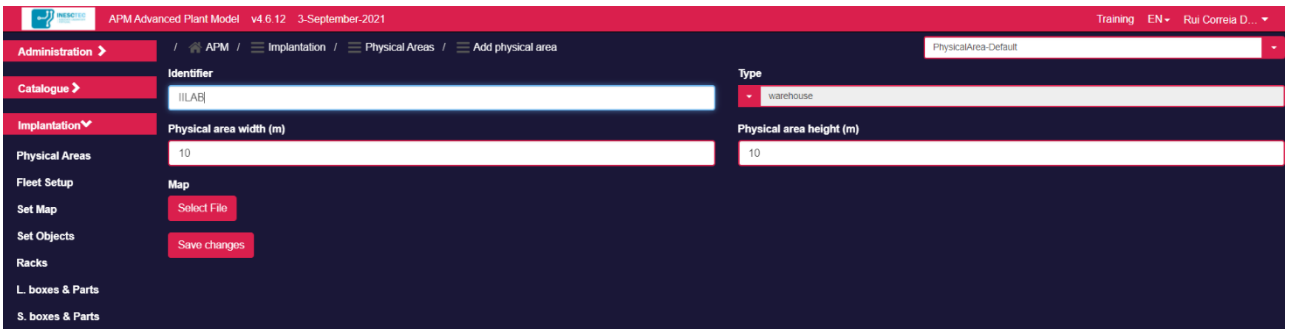
8.1 How to create a physical area

The Tool lets you model a given manufacturing area. The first thing you should do is to create a “Physical Area” in the Tool:

1. Go to “**Implantation / Physical Areas**”

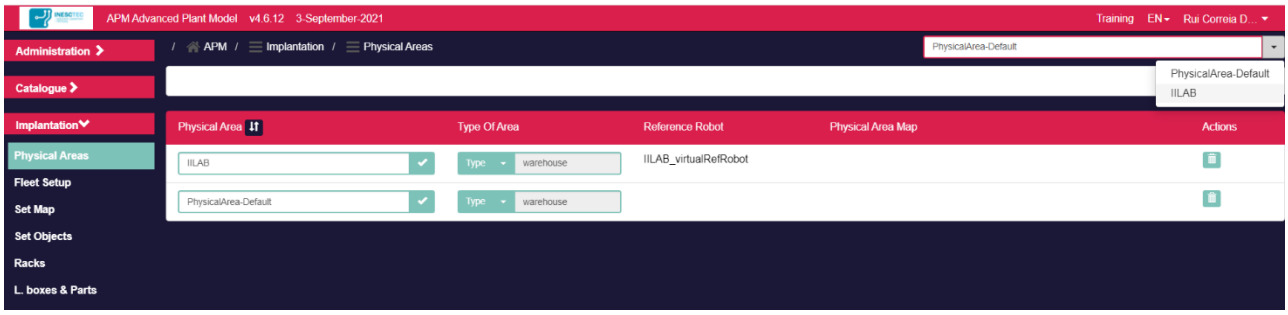


2. Press “**New Physical Area**” button (top right in the above screen)

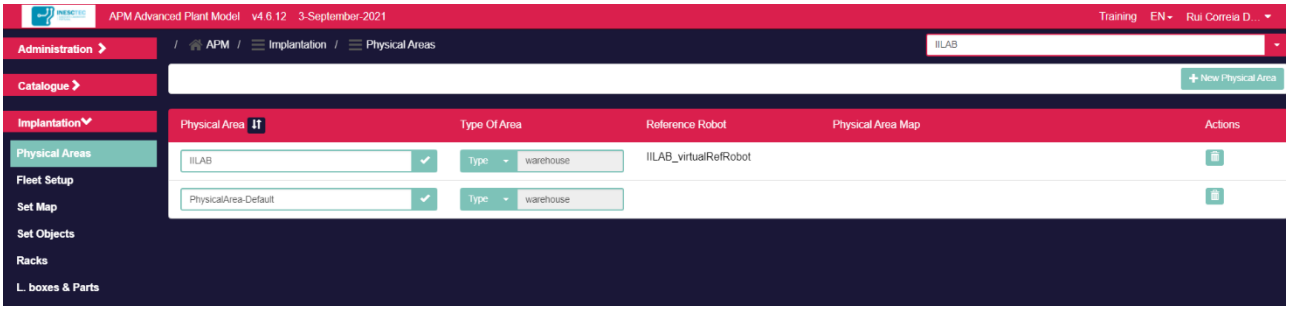


- Supply an **identifier** (e.g. IILAB)
- Specify the **type** (warehouse or assembly line)
- Specify the **width** and **height** (meters) of the physical area
- Press “**Save changes**”

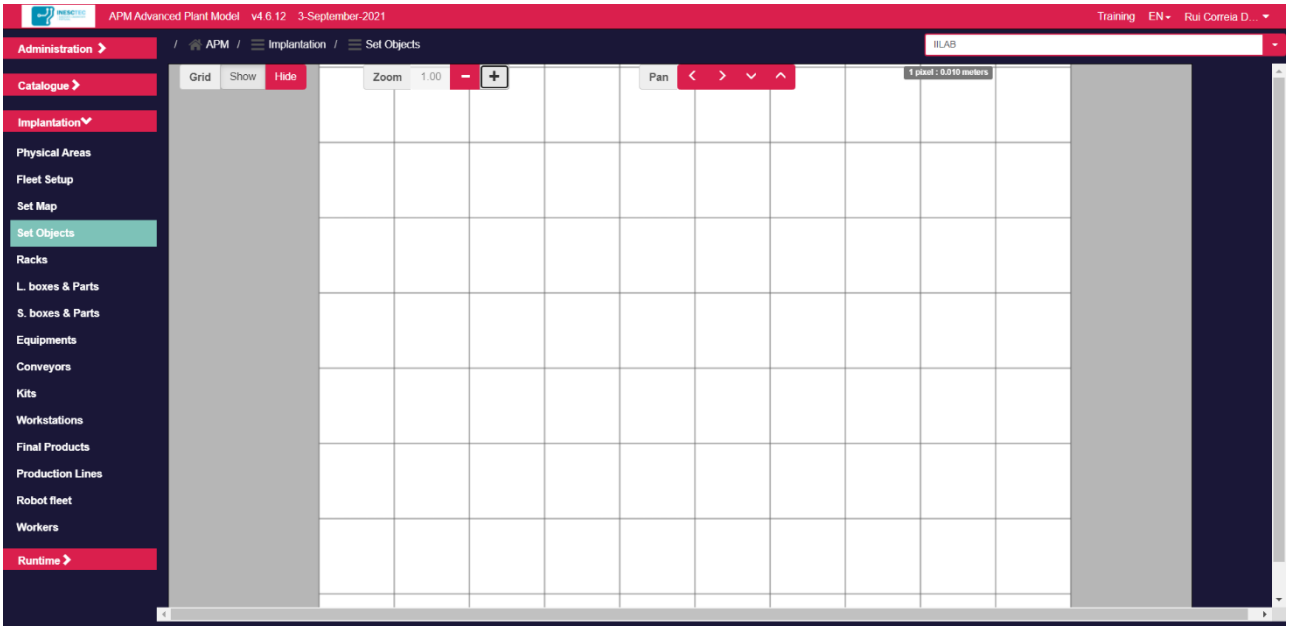
- Confirm the creation of the physical area (press the combo box on the top right).



- Select it so that you start modelling this new physical area.



- In case this is the first physical area you create, please remove the physical area with the name 'PhysicalArea-Default'.
- Go to "**Implantation / Set Objects**". This is the place where you will implant objects on the Physical Area.



The grid is configured so that each square's side length is 1 meter.

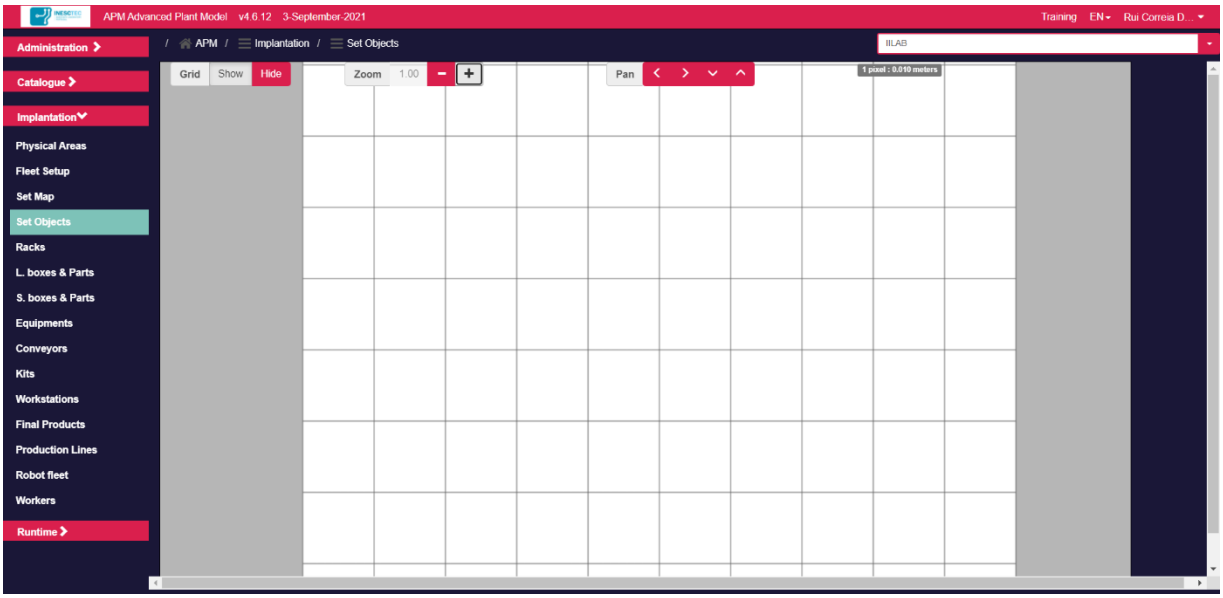
You can zoom in or zoom out by pressing the Zoom button.

You can move in the area by pressing the four Pan buttons.

8.2 How to implant objects on a physical area

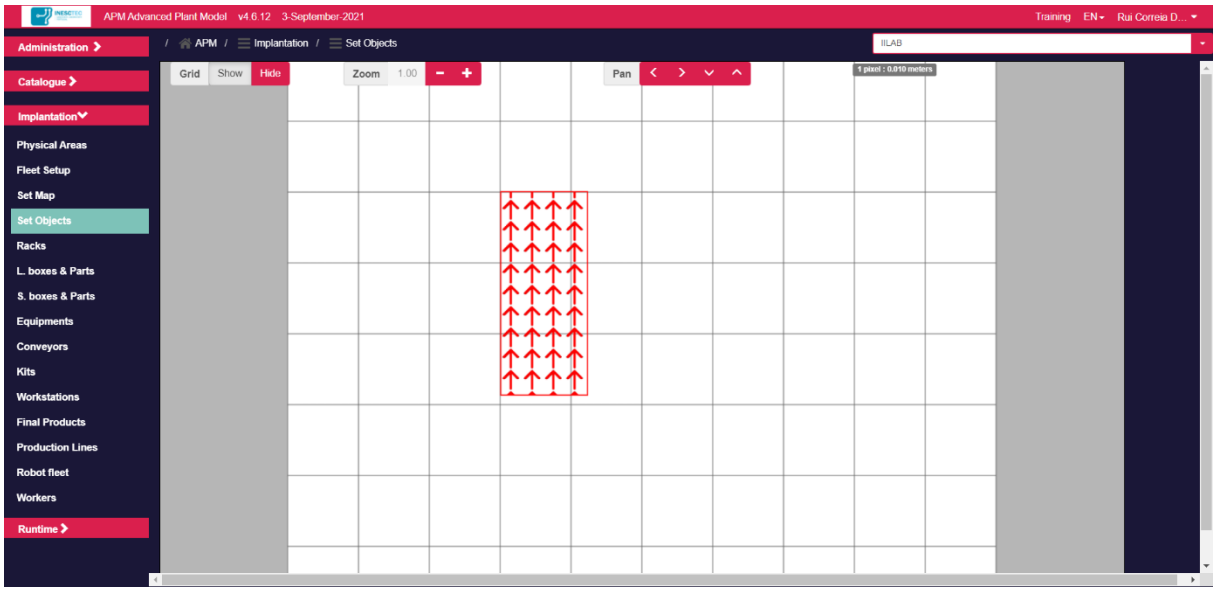
The Model of a given Physical Area is built by selecting objects defined in the Catalogue and adding them to the Physical Area.

1. Go to "**Implantation / Set Objects**" (make sure you have selected your Physical Area in the top right dropdown)

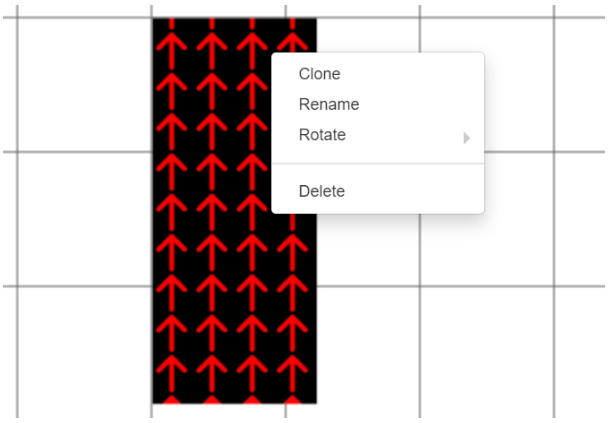


2. Press the right mouse button, you'll get options that let you select an object from the Catalogue

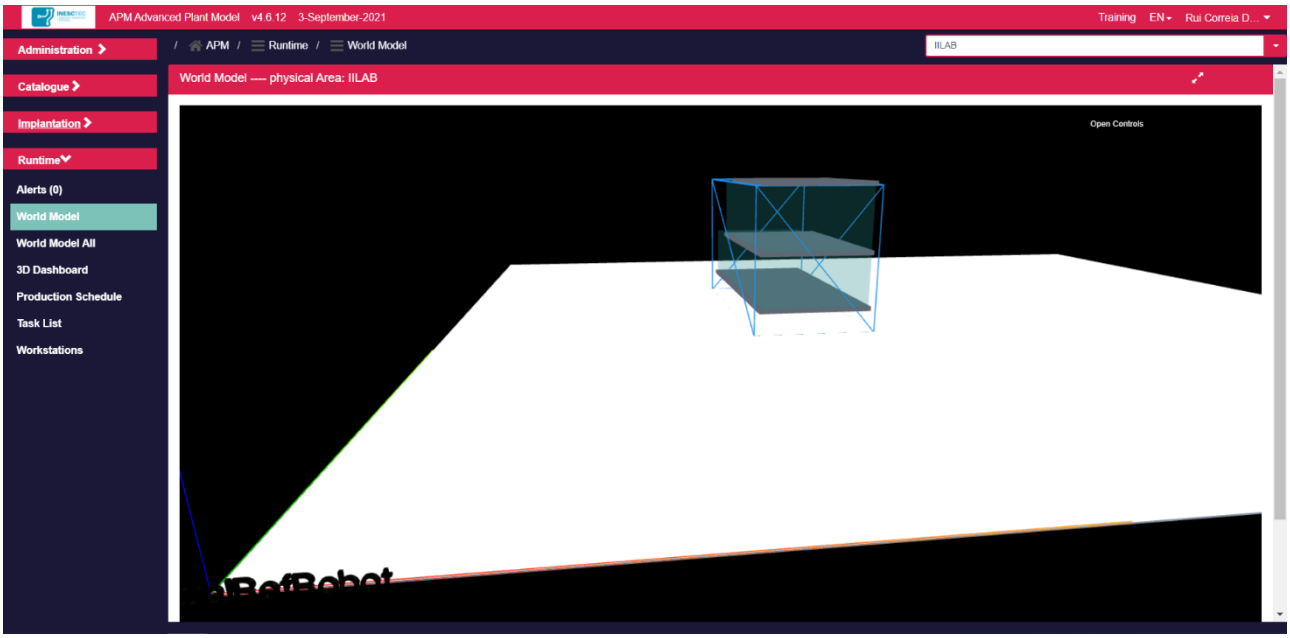
3. Select one of the objects (e.g. rack / PSA 2870x1225), a red rectangle will appear in the working space



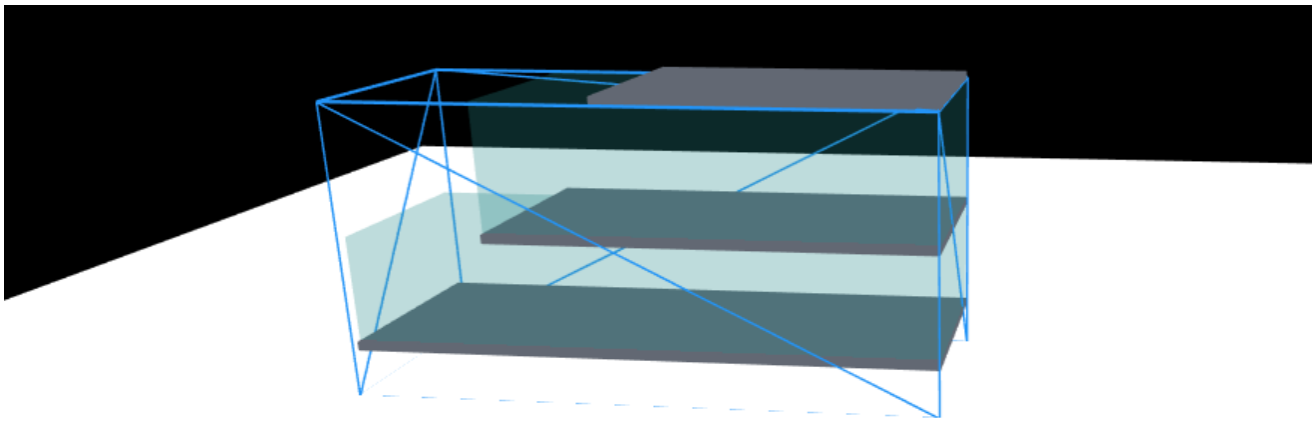
4. You can now select the object and move it in the working area
5. You can clone, rename, rotate, or delete the object by selecting it and pressing the right mouse button



6. Go to "**Runtime / World Model**", a 3D visualization of the Model created so far is shown



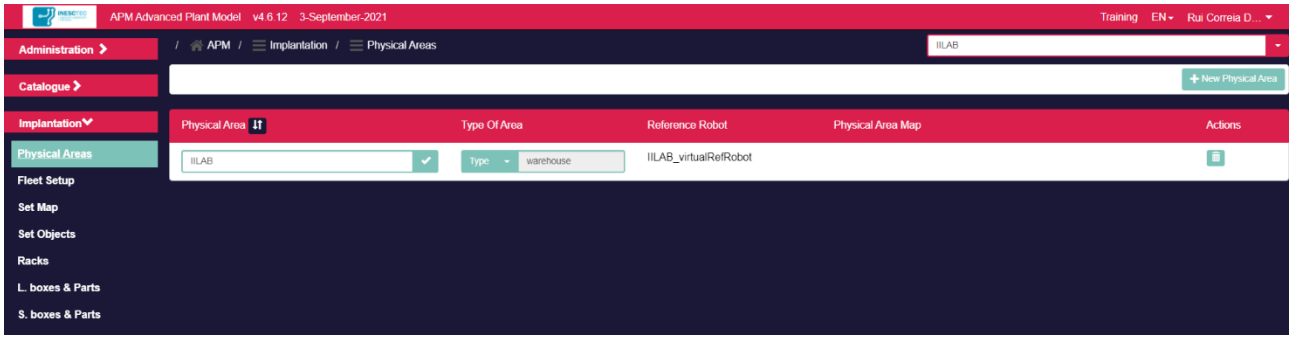
7. You can zoom in and out by using the mouse wheel
8. You can change the viewing perspective by selecting the left mouse button and moving the mouse around
9. You can also press the right mouse button and move the mouse (image is shifted)



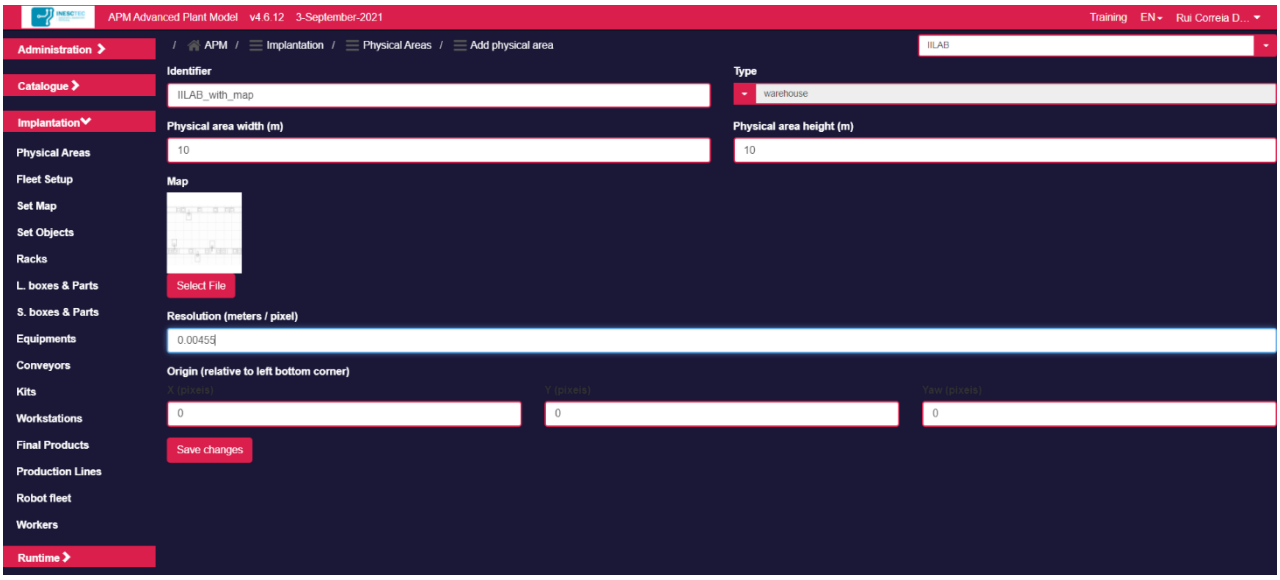
8.3 How to create a physical area with a map

The APM lets you model a given manufacturing area. The first thing you should do is to create a "Physical Area" You can supply a 2D image of the target area.

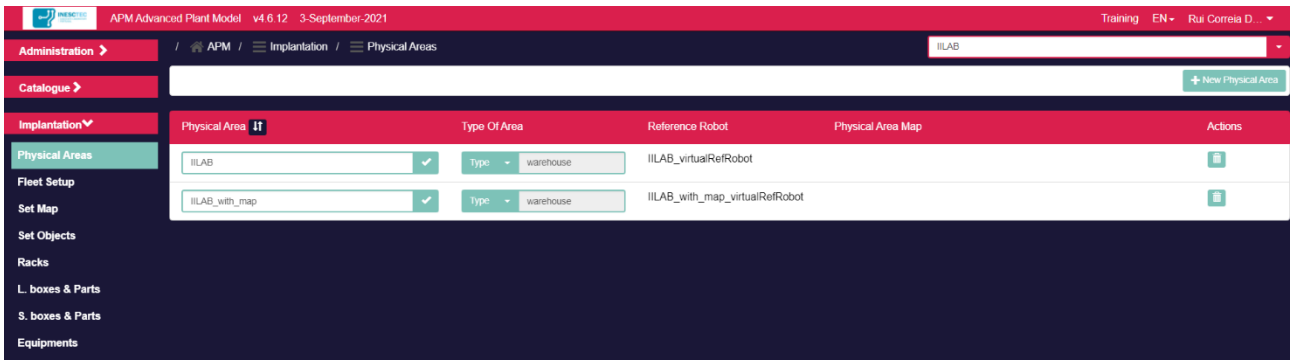
1. Go to "**Implantation / Physical Areas**"



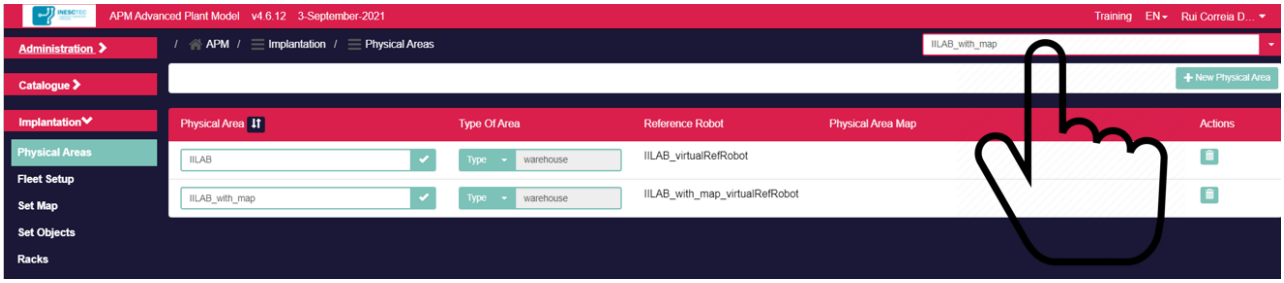
2. Press "New Physical Area" button (top right in the above screen)
   - Supply an **identifier** (e.g. IILAB)
   - Specify the **type** (warehouse or assembly line)
   - Press "**Map / Select file**" button
   - Supply a file containing the map for the physical area
   - Identify the scale of the map, i.e. how many meters correspond to a pixel



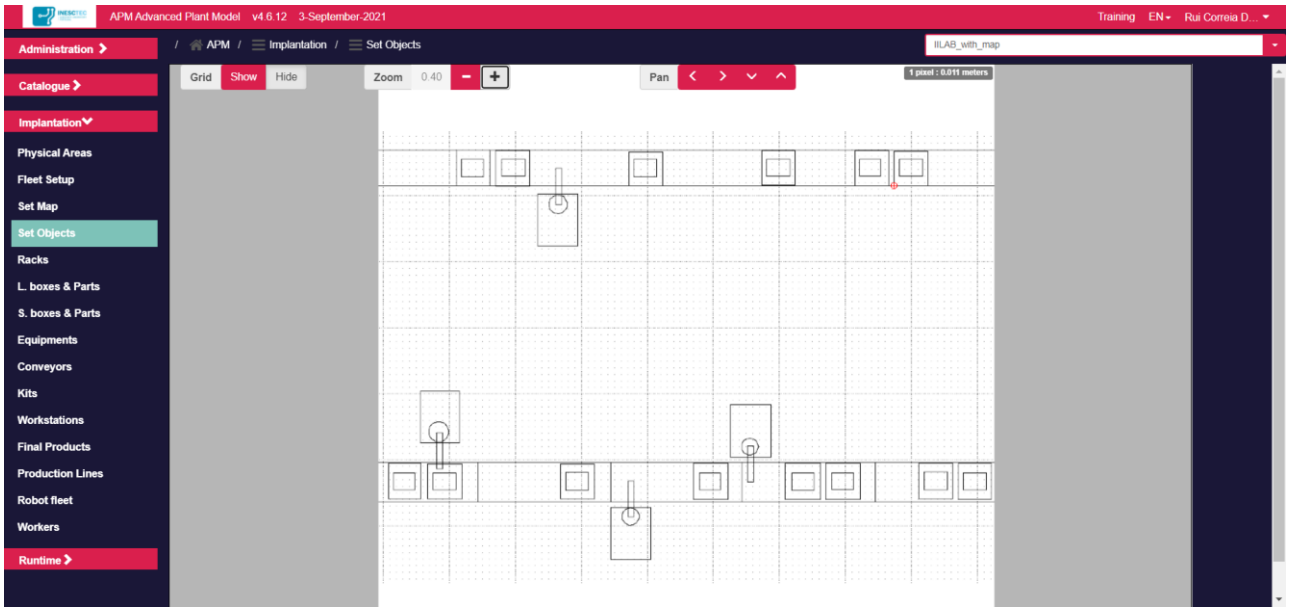
   - Press "**Save changes**"
   - Confirm the creation of the physical area (press the dropdown item on the top right).



- Select it so that you start modelling this new physical area.



- Go to "**Implantation / Set Objects**". This is the place where you will implant objects on the Physical Area.



The grid is configured so that each square's side length is 1 meter.

You can zoom in or zoom out by pressing the Zoom button.

You can move in the area by pressing the four Pan buttons.

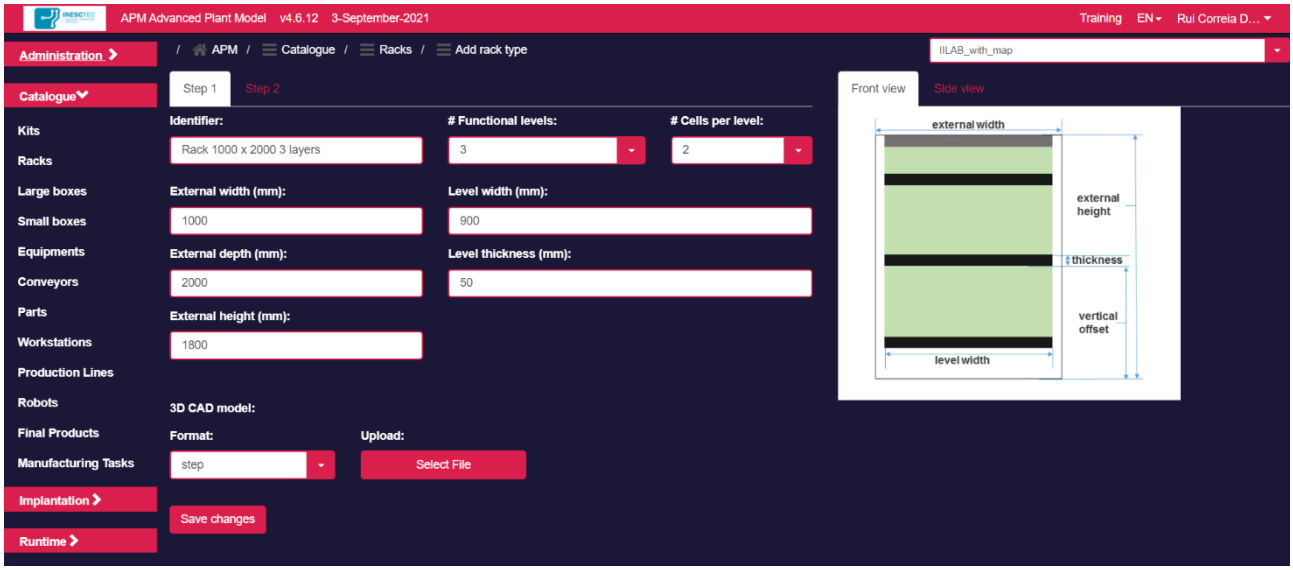
8.4 How to add a new rack to the catalogue

The Catalogue contains the 3D model of all the objects that may be used to build the Model of a given Physical Area.

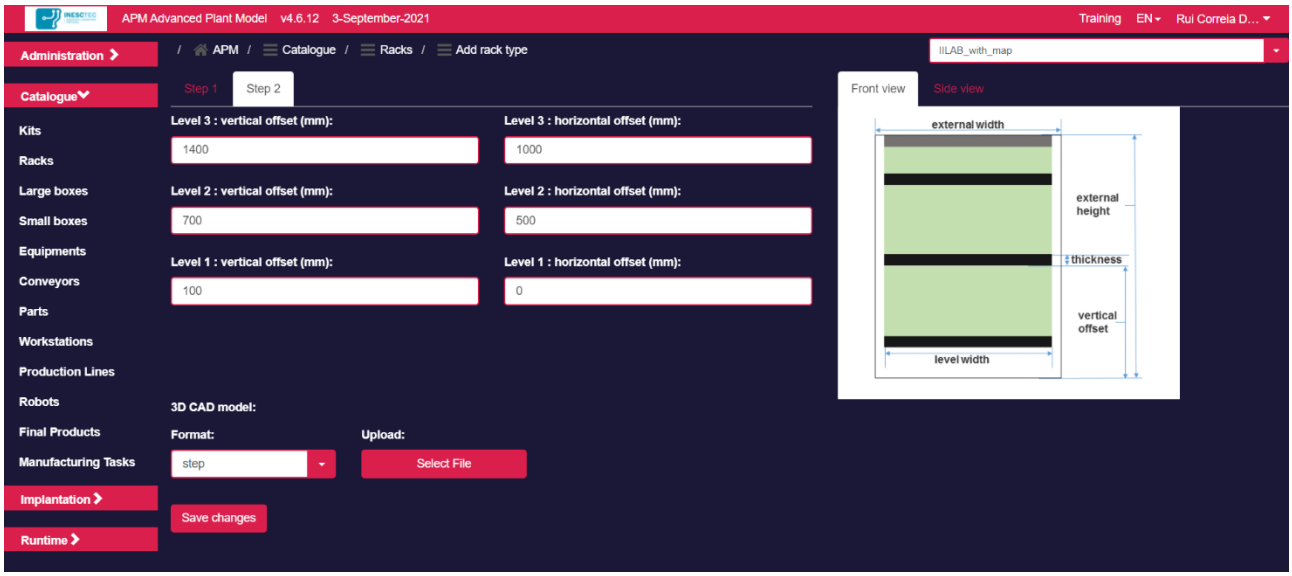
The Catalogue supports the following types of objects: Kits, Racks, Large boxes, Small boxes, Equipments, Conveyors, Parts, Workstations, Production Lines, Robots and Final Products.To add a new Rack to the Catalogue:

1. Go to "**Catalogue / Racks**"

2. Press the top right button "**New rack**" and fill the fields according to the picture (Front view)

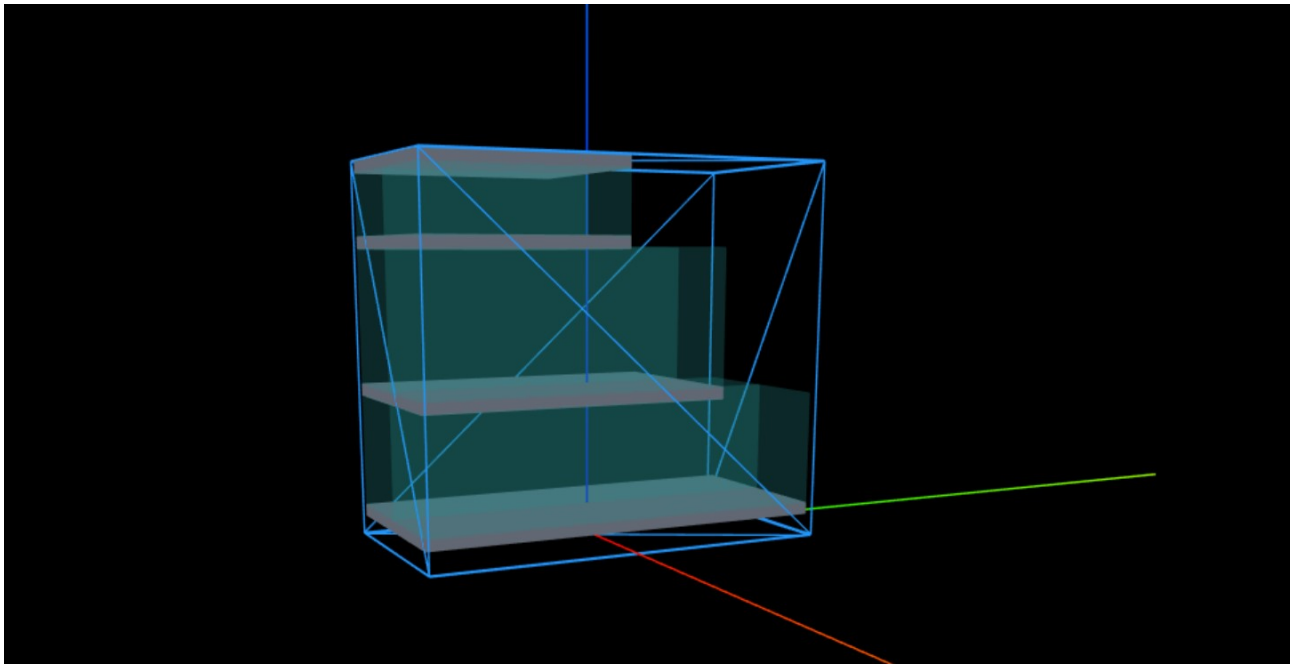


3. Select "**Step 2**" in the form and fill the fields according to the picture (Side view)



4. Press the "**Save changes**" button

5. In the list of Racks, press the icon and check if the defined Rack has the right form.



8.5 How to add a new rack to the catalogue with STEP

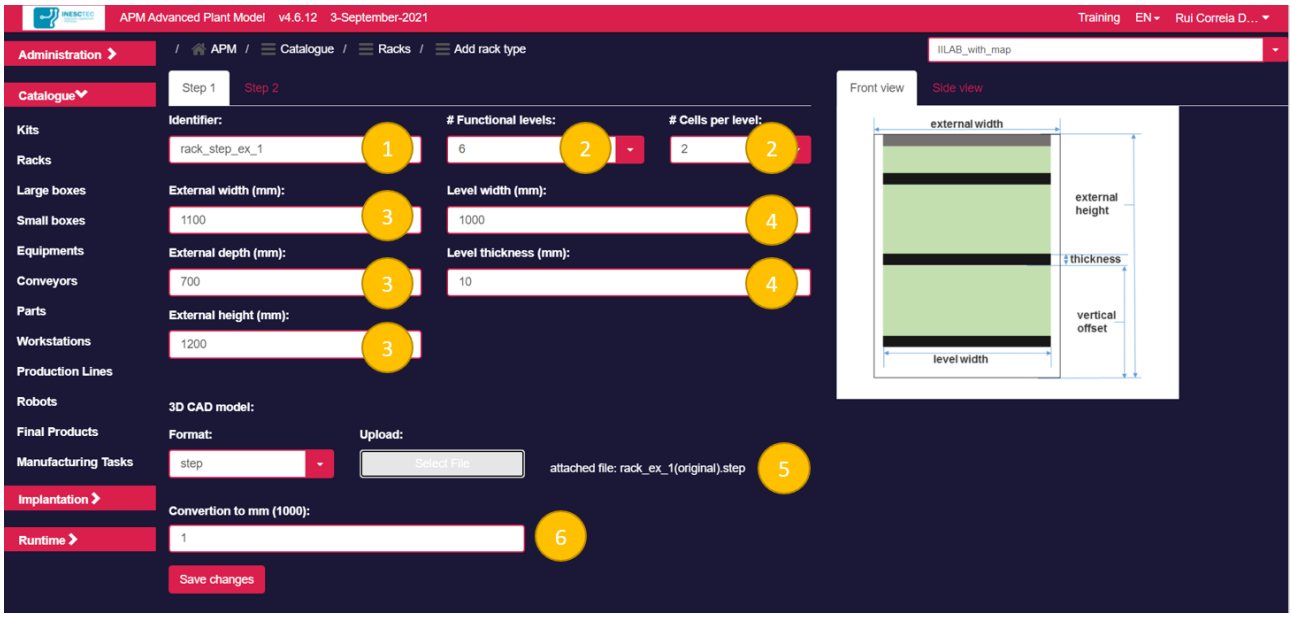
The Catalogue contains the 3D model of all the objects that may be used to build the Model of a given Physical Area.

The Catalogue supports the following types of objects: Kits, Racks, Large boxes, Small boxes, Equipments, Conveyors, Parts, Workstations, Production Lines, Robots and Final Products.

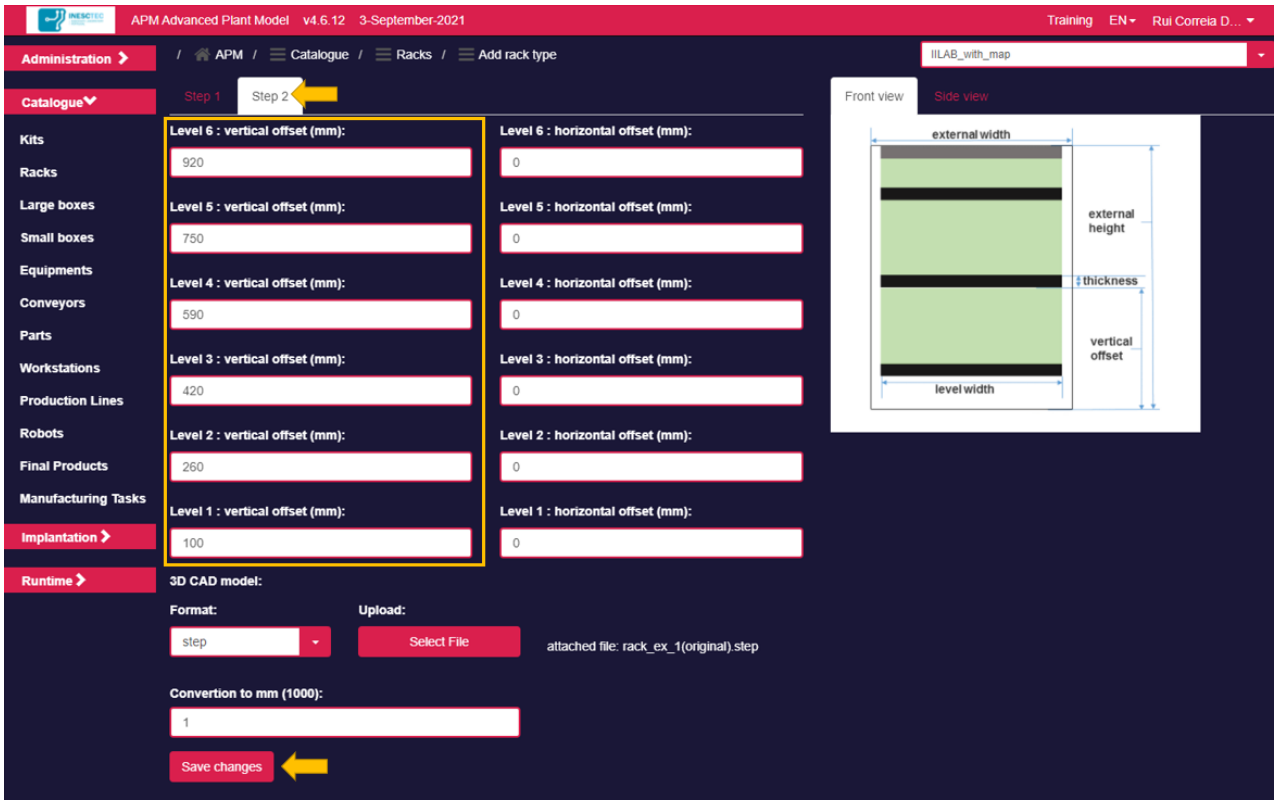
To add a new Rack to the Catalogue by using a STEP model:

1. Go to "**Catalogue / Racks**"

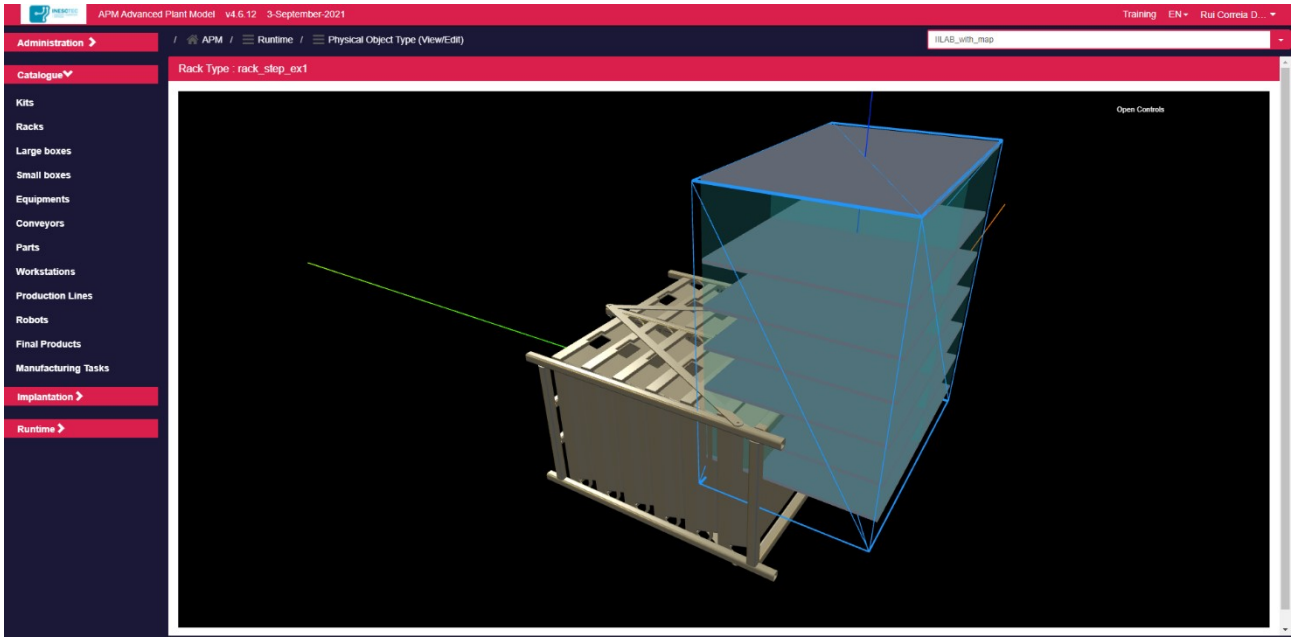
2. Press the top right button "**New rack**"
   - (1) Set the field: "**Identifier field**" (DON'T use spaces)
   - (2) Set the fields: "**Functional Levels**" and "**Cells per level**"
   - (3) Set the fields: "**External width**", "**External depth**" and "**External height**"
   - (4) Set the fields: "**Level width**" and "**Level thickness**"
   - (5) Press the "**3D CAD model / Select file**" button
   - (6) Set the "**Convertion to mm**" field



3. Select "**Step 2**" in the form and adjust the vertical offset of each level (In **Step 1** were defined 6 levels). Then press the "**Save changes**" button and wait. When the upload completes you will be redirected to the list of Racks in the catalogue.

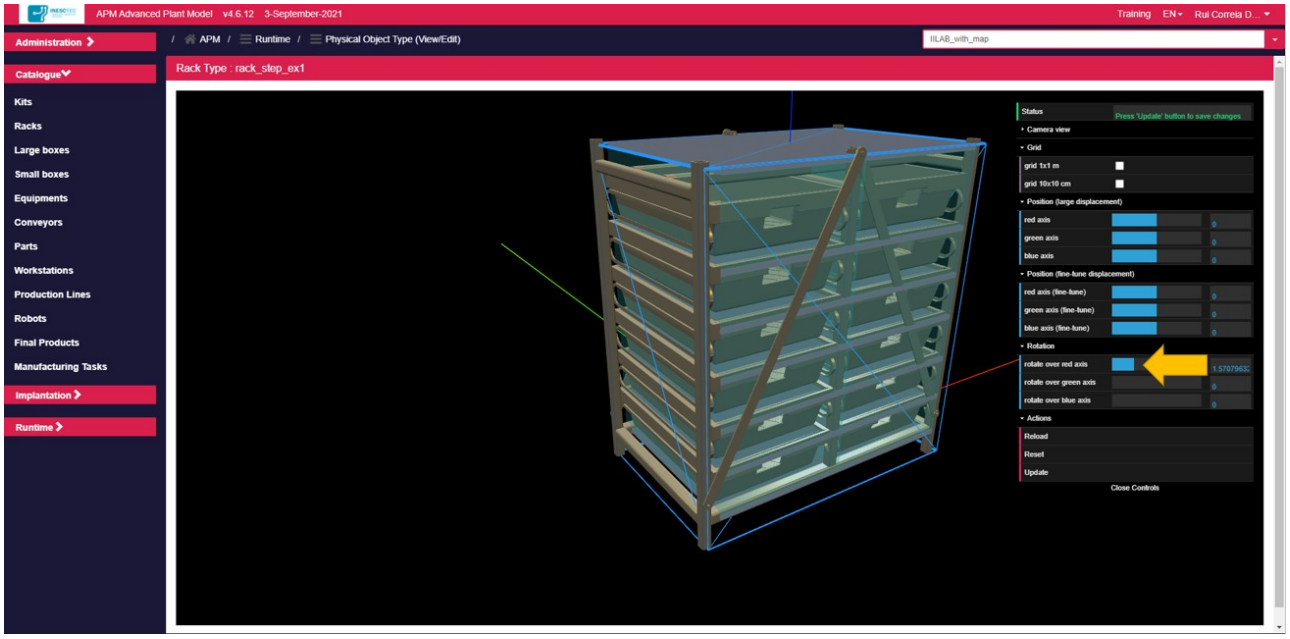


4. In the list of Racks, press the icon and check if the defined Rack has the right form. It may be necessary to align the CAD model with the respective Bounding Volume (like in the picture below).



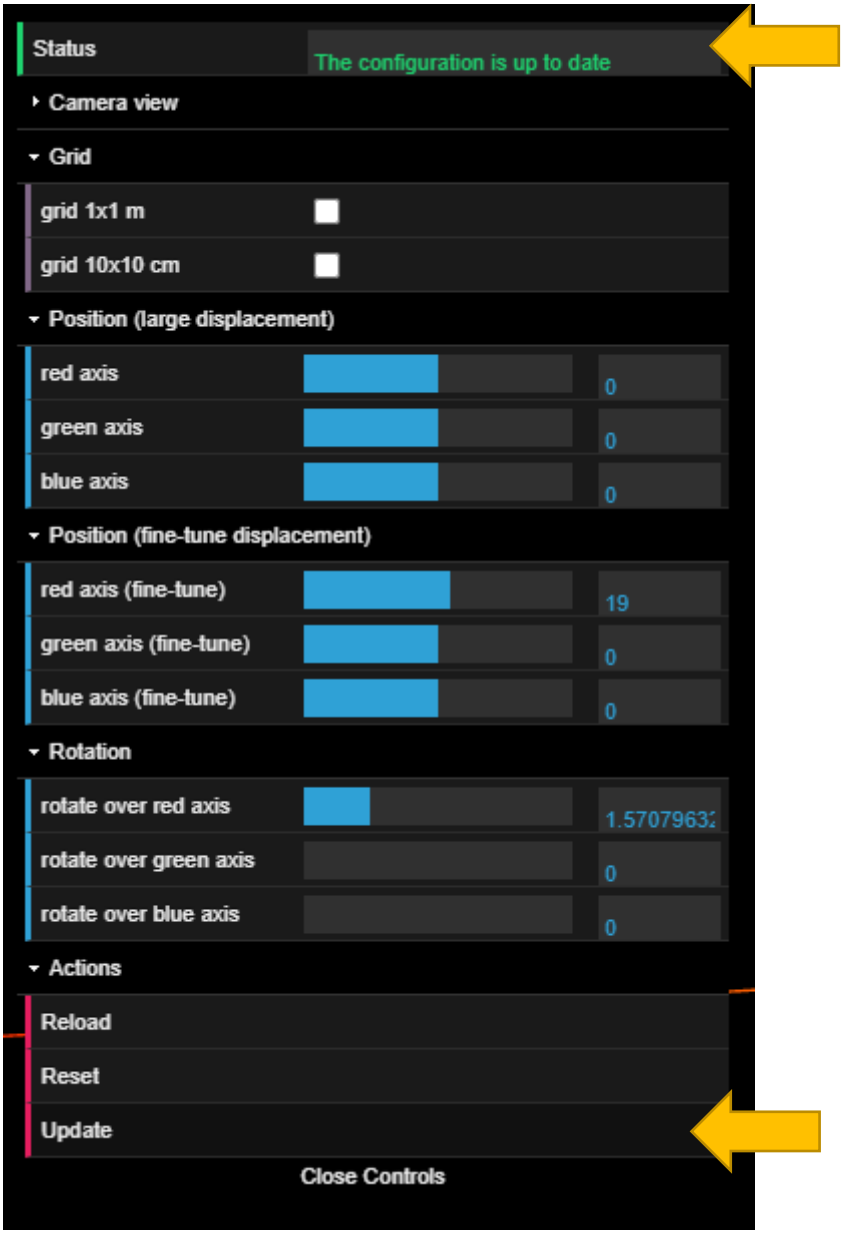
5. To align the CAD model with the respective Bounding Volume, press the top right button "**Open Controls**". The following menu comprising four categories will expand:
   - **Status**: gives feedback about the user's actions.
   - **Position**: adjusts the CAD model position.
   - **Rotation**: adjusts the CAD model orientation.
   - **Actions**: allows to **undo**, **reset** and **update** the configuration.
     - **Undo :** loads the last saved configuration.
     - **Reset :** sets all numeric configuration values to zero.
     - **Update:** saves the current configuration.

a. Adjust CAD model **orientation** using the **Rotation sliders**. Each slider performs the rotation over a specific axis (red, green, or blue).



b. Adjust CAD model **location** using the **Position sliders**. Each slider performs a translation over a specific axis (red, green, or blue).

c. Once the CAD model is aligned with the Bounding Volume, press Update button to save the configuration. A message is presented “The configuration is up to date” confirming the action.



8.6 How to add a new equipment to the catalogue

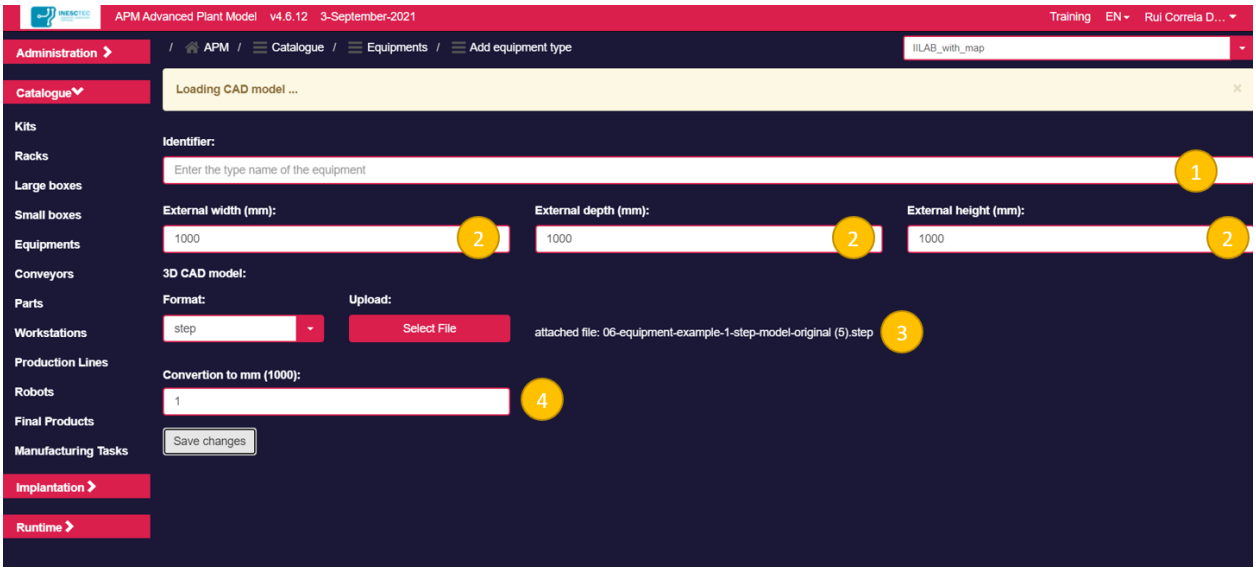
The Catalogue contains the 3D model of all the objects that may be used to build the Model of a given Physical Area.

The Catalogue supports the following types of objects: Kits, Racks, Large boxes, Small boxes, Equipments, Conveyors, Parts, Workstations, Production Lines, Robots and Final Products.

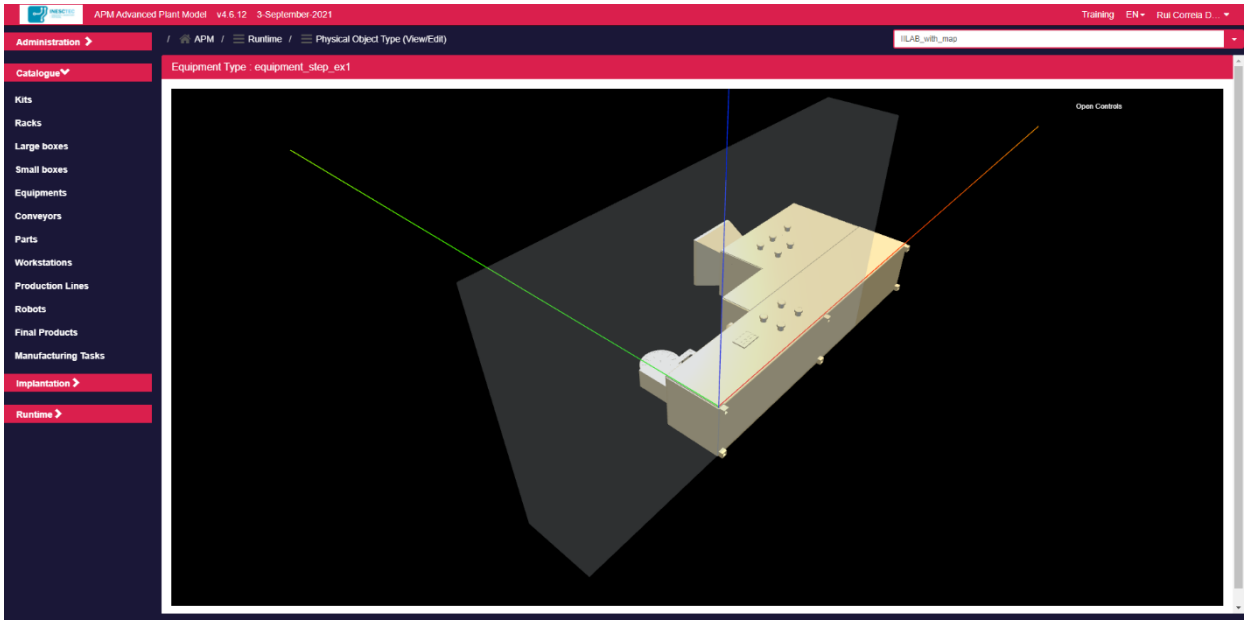
To add a new Equipment to the Catalogue by using a STEP model:

1. Go to "**Catalogue / Equipments**"
2. Press the top right button "**New equipment**"
   - (1) Set the field "Identifier field" (DON'T use blank spaces)
   - (2) Set the fields: "External width", "External depth" and "External height"

   You may optionally associate a STEP model with the Equipment (DON'T use spaces in the Identifier field)
   - (3) Press the "3D CAD model / Select file" button
   - (4) Set the "Convertion to mm" field
3. Press the "**Save changes**" button and wait. When the upload completes you will be redirected to the list of Equipments in the catalogue.

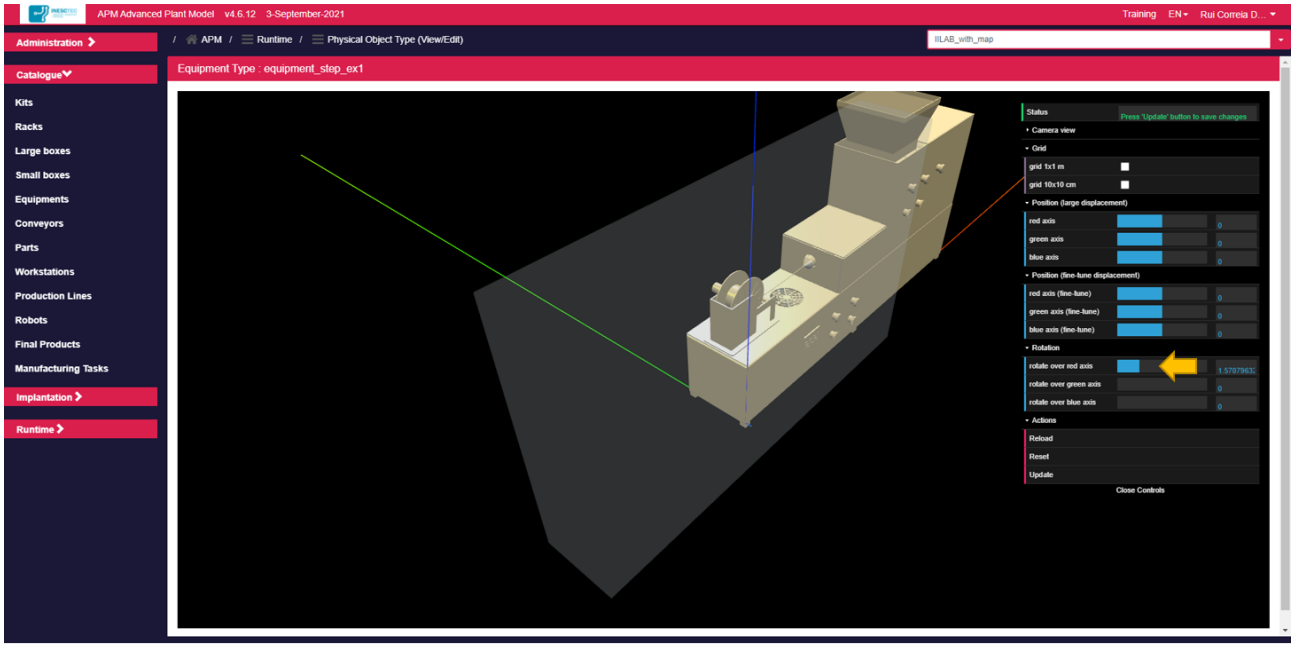


4. In the list of Equipments, press the icon and check if the defined Equipment has the right form. It may be necessary to align the CAD model with the respective Bounding Volume (like in the picture below).

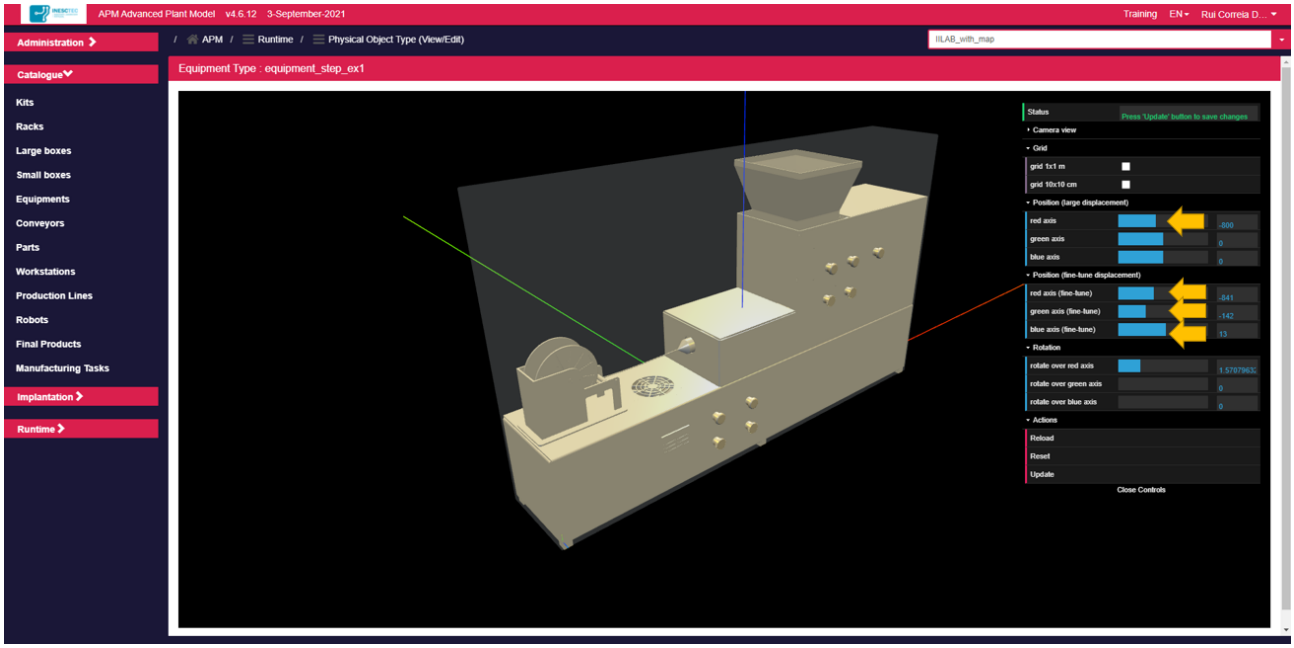


5. To align the CAD model with the respective Bounding Volume, press the top right button "**Open Controls**". The following menu comprising four categories will expand:
   - **Status**: gives feedback about the user's actions.
   - **Position**: adjusts the CAD model position.
   - **Rotation**: adjusts the CAD model orientation.
   - **Actions**: allows to **undo**, **reset** and **update** the configuration.
     - **Undo:** loads the last saved configuration.
     - **Reset:** sets all numeric configuration values to zero.
     - **Update:** saves the current configuration.

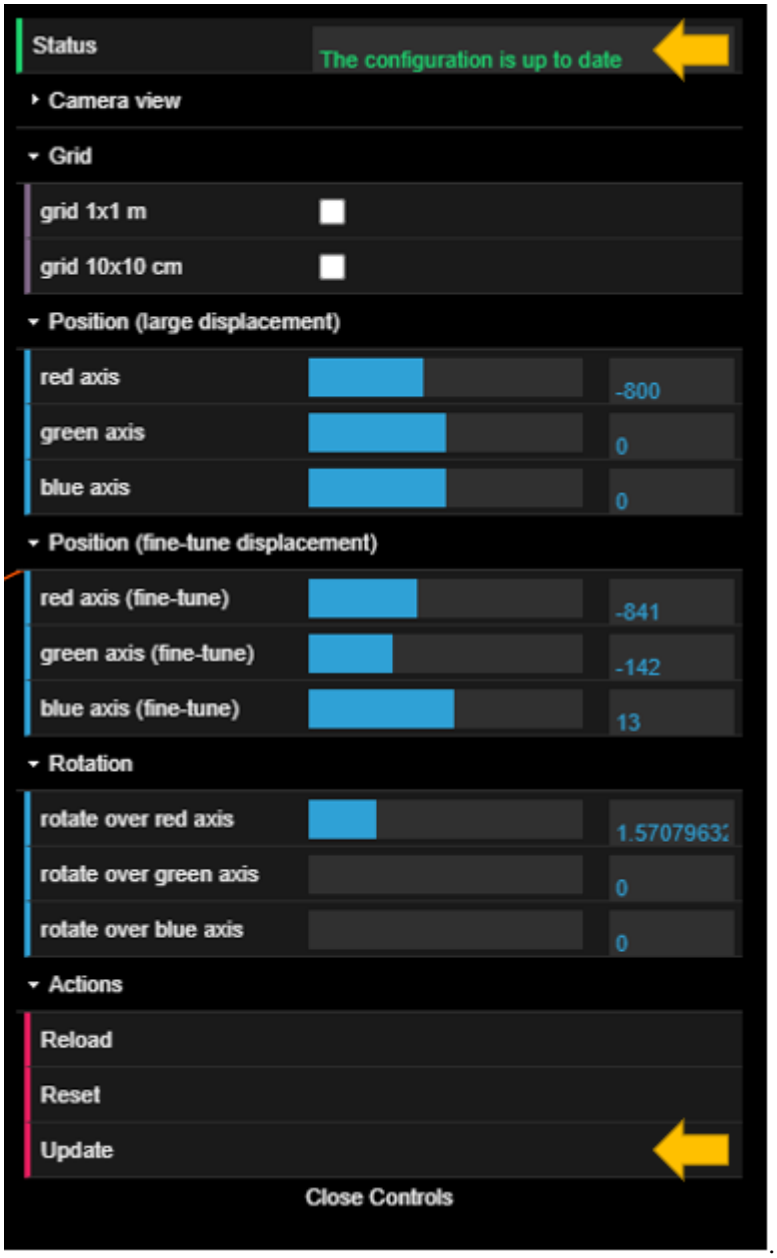
a. Adjust CAD model **orientation** using the **Rotation sliders**. Each slider performs the rotation over a specific axis (red, green, or blue).



b. Adjust CAD model **location** using the **Position sliders**. Each slider performs a translation over a specific axis (red, green, or blue).



c. Once the CAD model is aligned with the Bounding Volume, press **Update** button to save the configuration. A message is presented “The configuration is up to date” confirming the action.



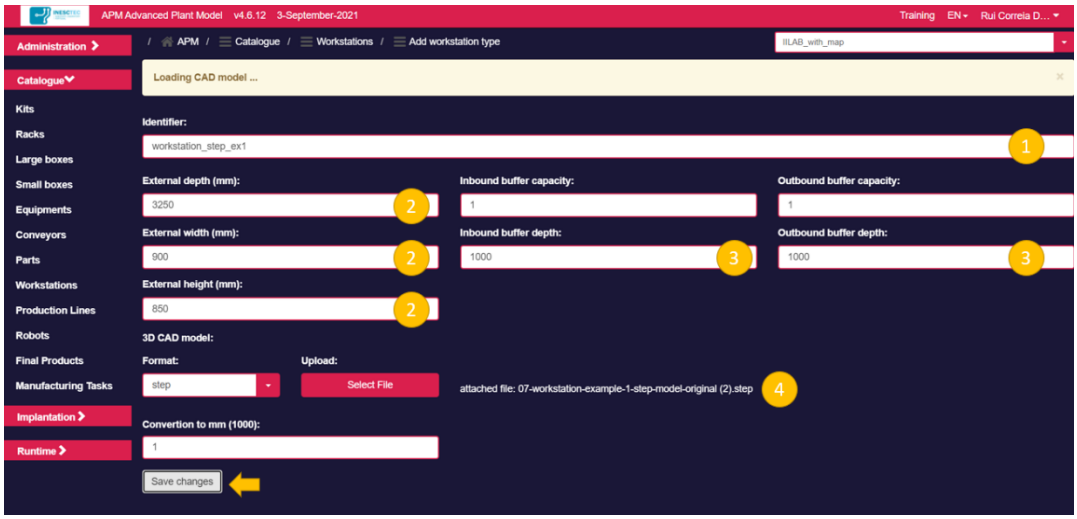
8.7 How to add a new workstation to the catalogue

The Catalogue contains the 3D model of all the objects that may be used to build the Model of a given Physical Area.

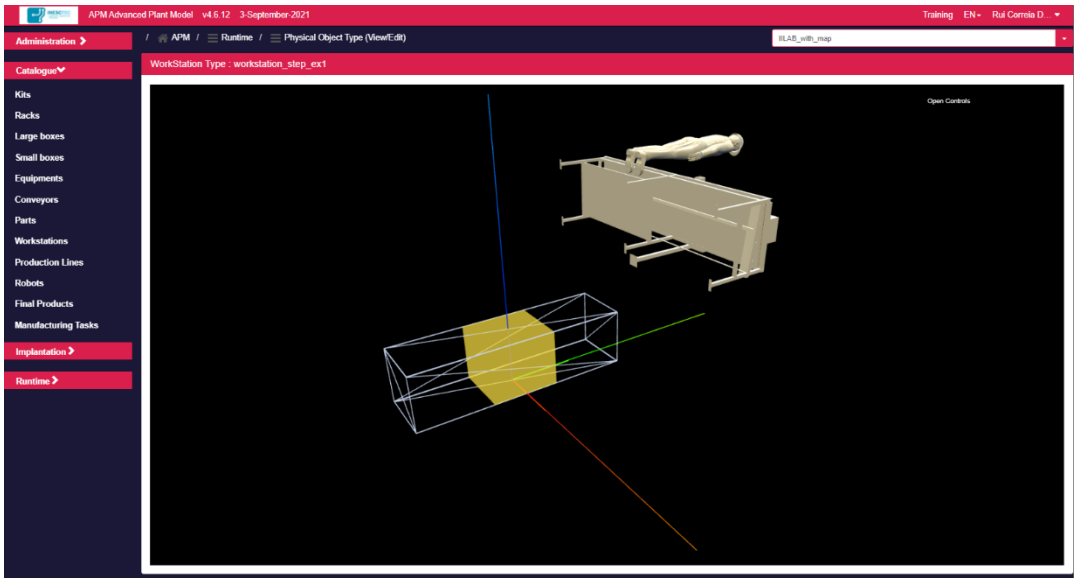
The Catalogue supports the following types of objects: Kits, Racks, Large boxes, Small boxes, Equipments, Conveyors, Parts, Workstations, Production Lines, Robots and Final Products.To add a new Workstation to the Catalogue:

1. Go to "**Catalogue / Workstations**"
2. Press the top right button "**New workstation**" and set the description fields (a workstation may have an inbound buffer and an outbound buffer which correspondent to the inbound / outbound spaces that may store temporarily the work in progress)
   - (1) Set the field "Identifier field" (DON'T use spaces)
   - (2) Set the fields: "External width", "External depth" and "External height"

   You may optionally associate a STEP model with the workstation (DON'T use spaces in the Identifier field)
   - (3) Press the "3D CAD model / Select file" button
   - (4) Set the "Convertion to mm" field
3. Press the "**Save changes**" button and wait. When the upload completes you will be redirected to the list of Workstations in the catalogue.

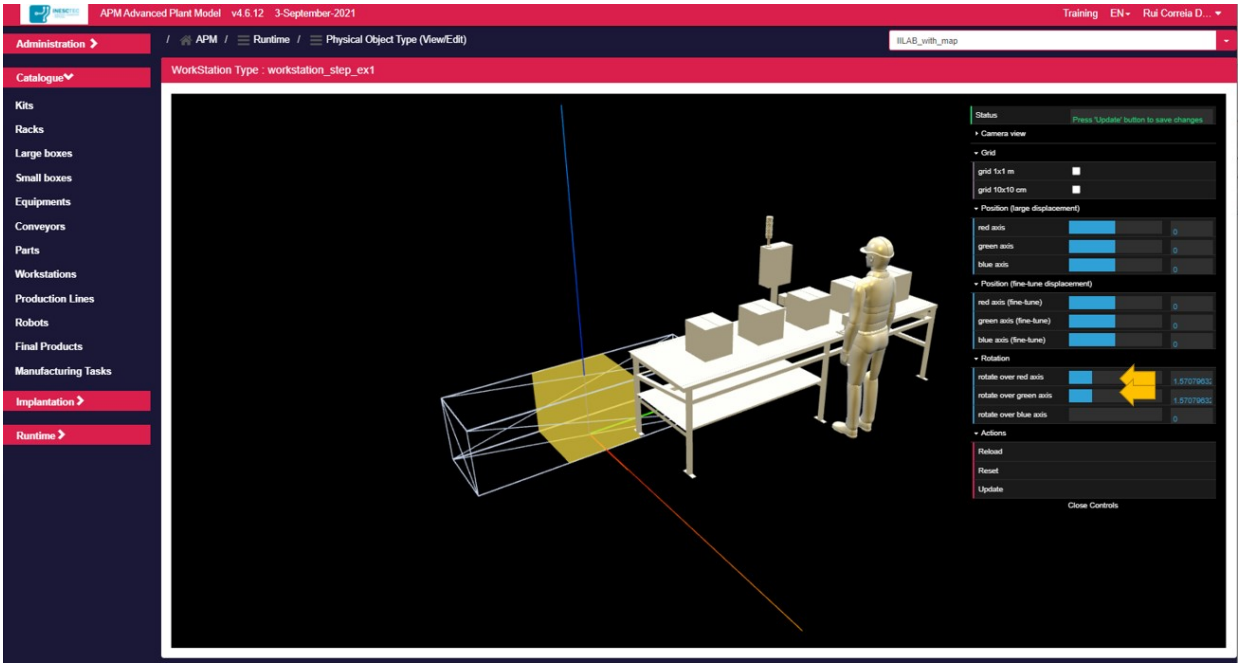


4. In the list of Workstations, press the icon and check if the defined Workstation has the right form. It may be necessary to align the CAD model with the respective Bounding Volume (like in the picture below).

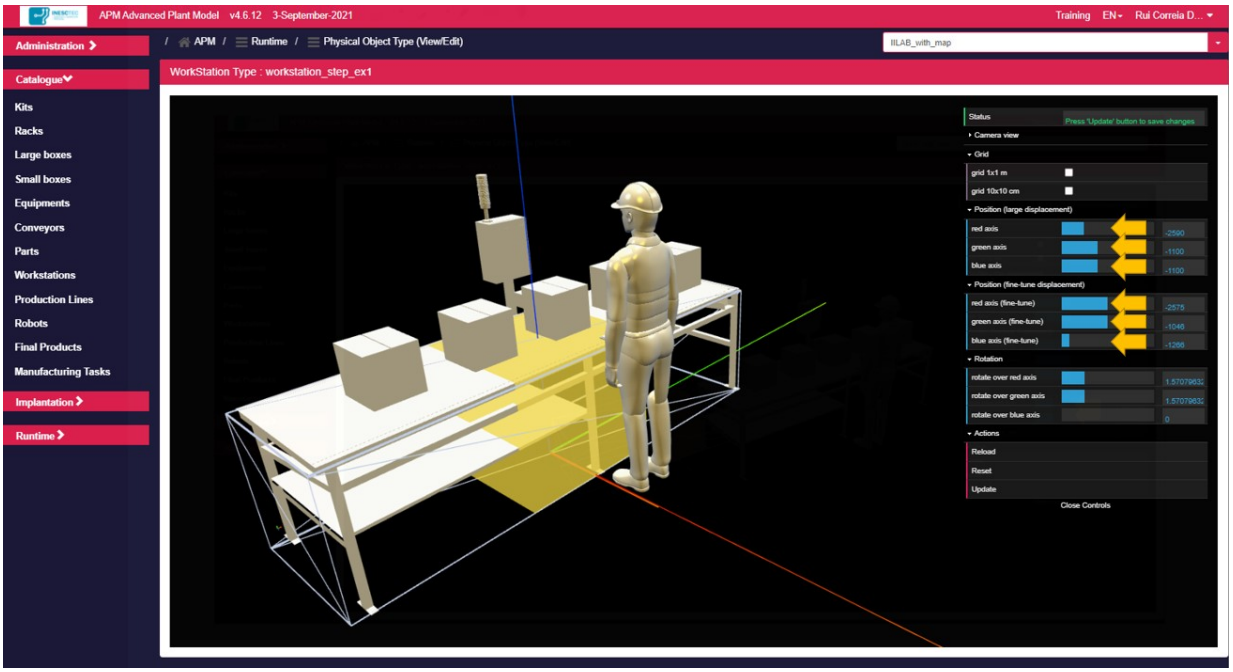


5. To align the CAD model with the respective Bounding Volume, press the top right button "**Open Controls**". The following menu comprising four categories will expand:
   - **Status**: gives feedback about the user's actions.
   - **Position**: adjusts the CAD model position.
   - **Rotation**: adjusts the CAD model orientation.
   - **Actions**: allows to **undo**, **reset** and **update** the configuration.
     - **Undo:** loads the last saved configuration.
     - **Reset:** sets all numeric configuration values to zero.
     - **Update:** saves the current configuration.

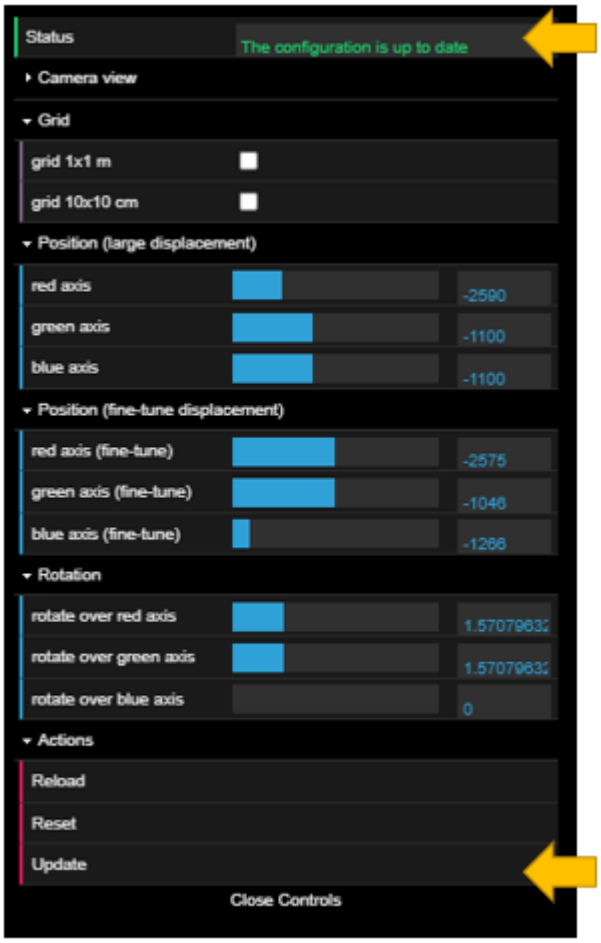
a. Adjust CAD model **orientation** using the **Rotation sliders**. Each slider performs the rotation over a specific axis (red, green, or blue).



b. Adjust CAD model **location** using the **Position sliders**. Each slider performs a translation over a specific axis (red, green, or blue).



c. Once the CAD model is aligned with the Bounding Volume press Update button to save the configuration. A message is presented “The configuration is up to date” confirming the action.

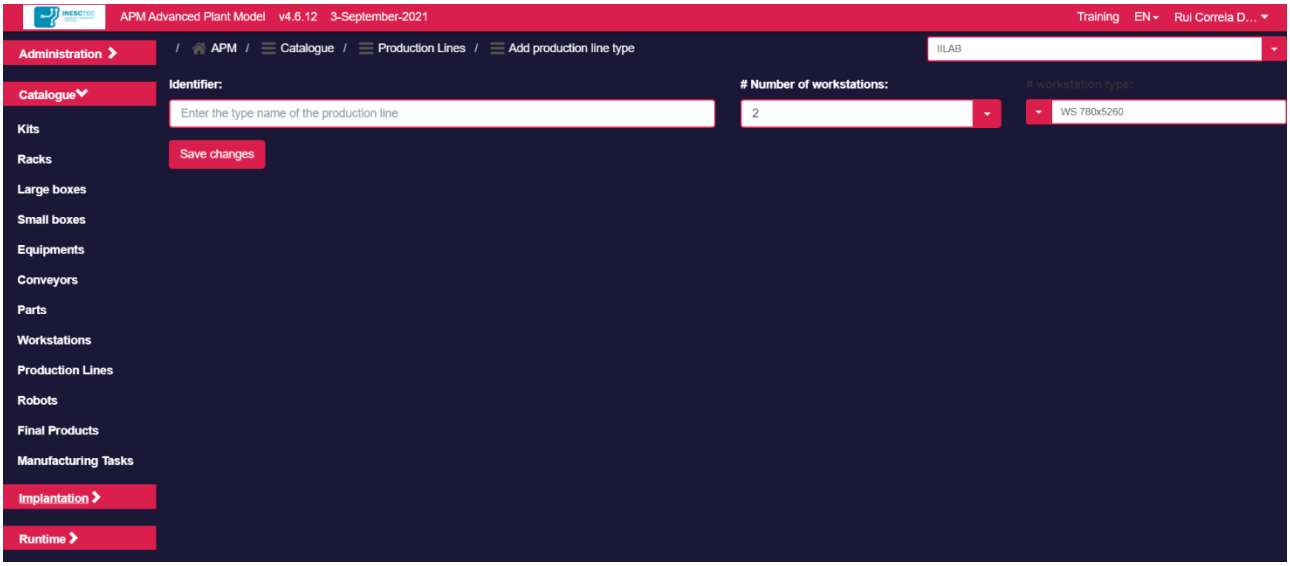


8.8 How to add a new production line to the catalogue

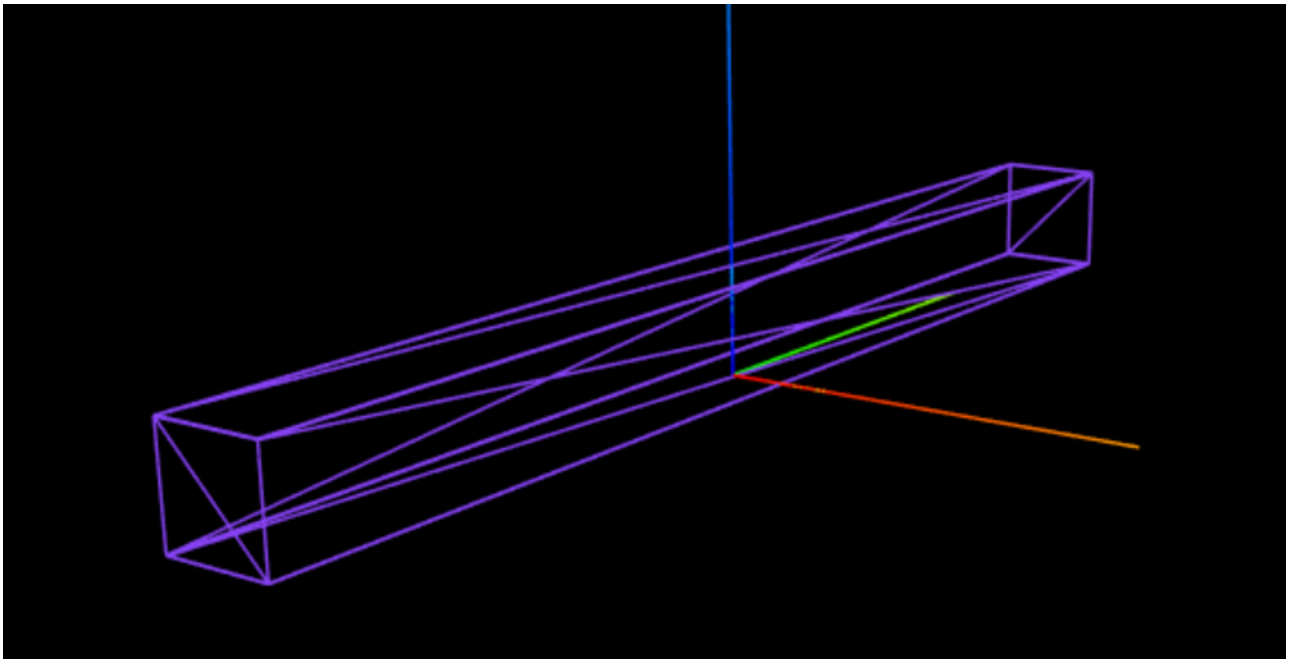
The Catalogue contains the 3D model of all the objects that may be used to build the Model of a given Physical Area.

The Catalogue supports the following types of objects: Kits, Racks, Large boxes, Small boxes, Equipments, Conveyors, Parts, Workstations, Production Lines, Robots and Final Products. To add a new Production Line to the Catalogue:

1. Go to "**Implantation / Production Lines**"
2. Press the top right button "**New production line**" and set the description fields (a production line comprises several workstation in line; you must have already created the model of the workstation)
3. You may optionally associate a STEP model with the production line (DON'T use spaces in the Identifier field)
   - Press the "**Save changes**" button



4. In the list of Racks, press the icon and check if the defined Rack has the right form (if specified a STEP model for the workstation, you will you see it in the 3D visualization in a future version of the software).

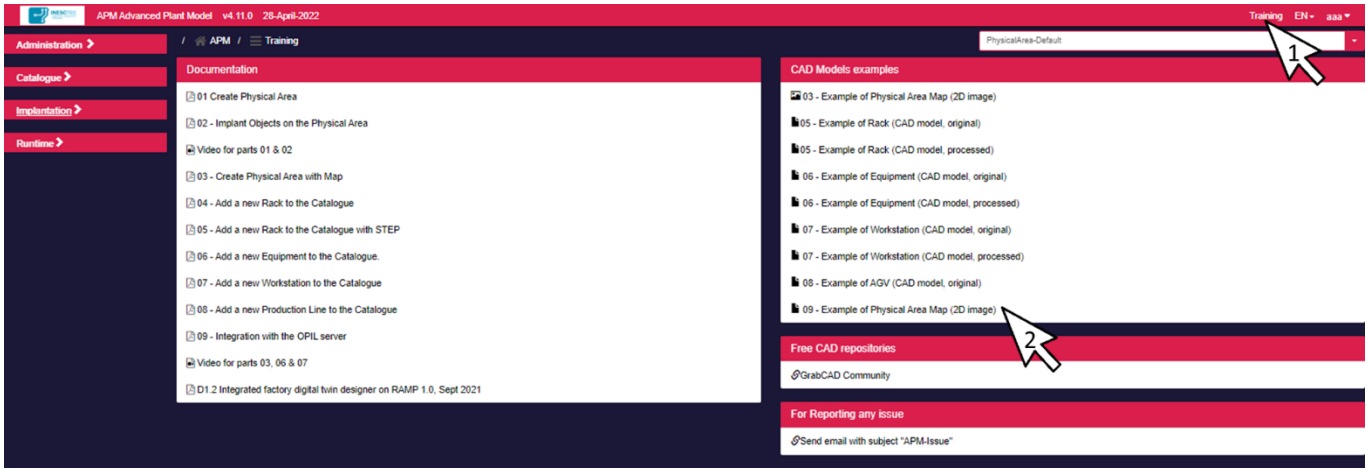


8.9 How to integrate the APM with the OPIL Server, part 1

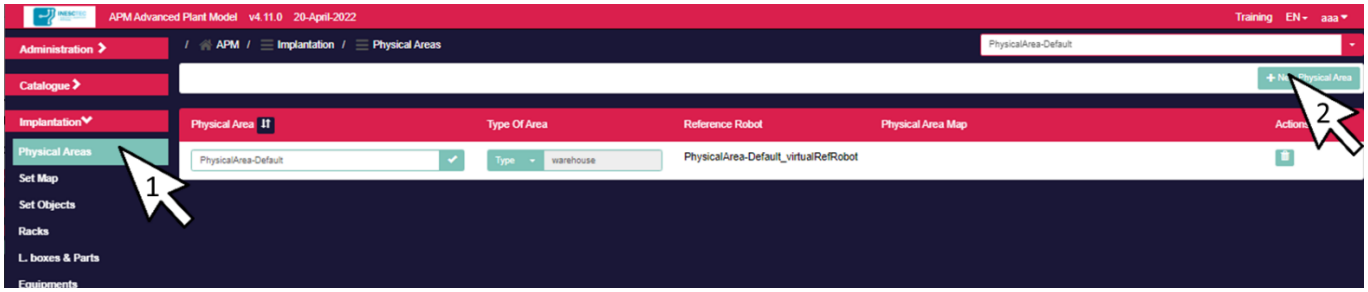
The APM lets you model a given manufacturing area and export the data in a format compatible with the OPIL server (Open Platform for Innovations in Logistics). This data comprises three files (*layout_map_annotations.ini*, *layout_map_image.png* and *layout_map.yaml*.) that the APM can generate after you have modeled the physical area where the OPIL robots will operate.

The first thing you should do is to create a "Physical Area" in the APM. You should supply a 2D image of the target area.

1. Go to "**Training**" section and download the image with the name *09 - Example of Physical Area Map (2D image).*



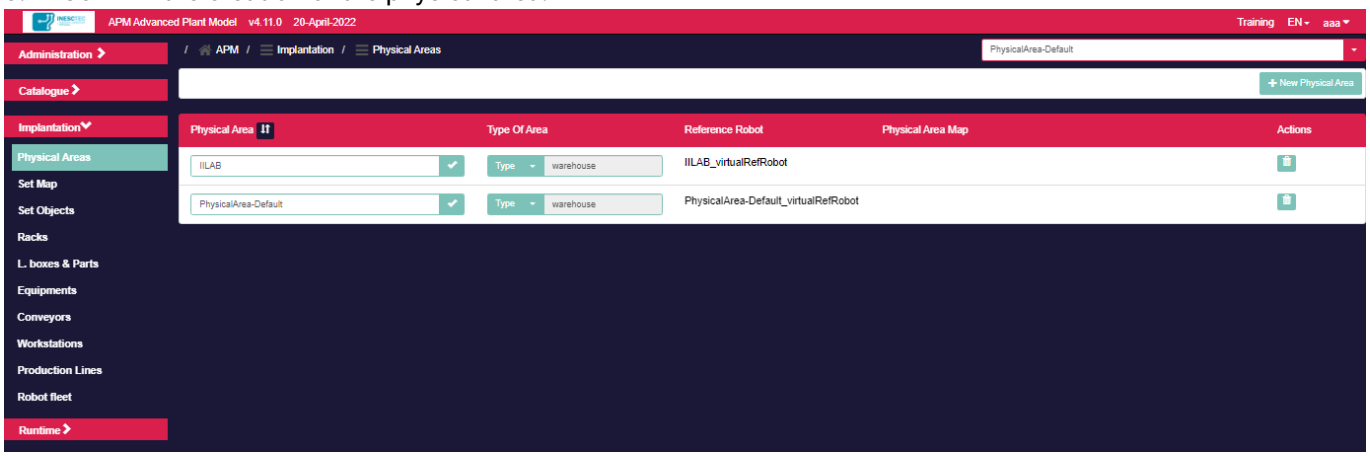
2. Go to "**Implantation / Physical Areas**". Press "**New Physical Area**" button (top right in the above screen)



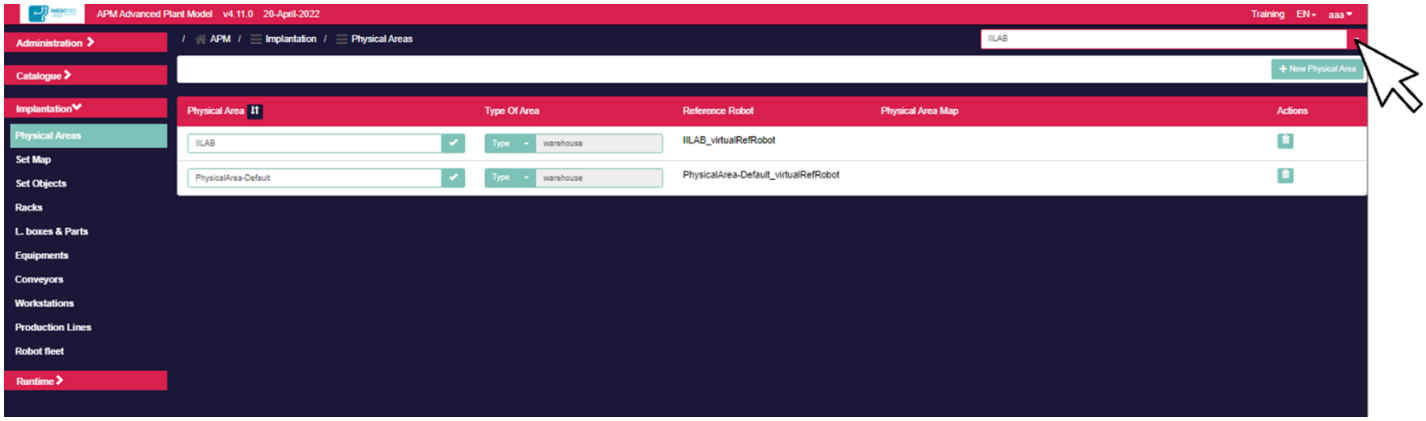
- Supply an **identifier** (e.g. IILAB).
  NOTE: if you also want the APM to visualize the navigation of OPIL robots in the 3D visualization of the APM, you must use this specific name for the physical area: 'OpilArea'.
- Specify the **type** (warehouse or assembly line)
- Press "**Map / Select file**" button
- Supply a **.png** file containing the map for the physical area. For this example, the image downloaded in step 1 was used, which is available in the training section with the name *09 - Example of Physical Area Map (2D image).*
- Identify the scale of the map, i.e. how many meters correspond to a pixel. The scale of the map in this example is 0.05, so that each pixel represents a 5cm x 5cm square.

- Press “**Save changes**”

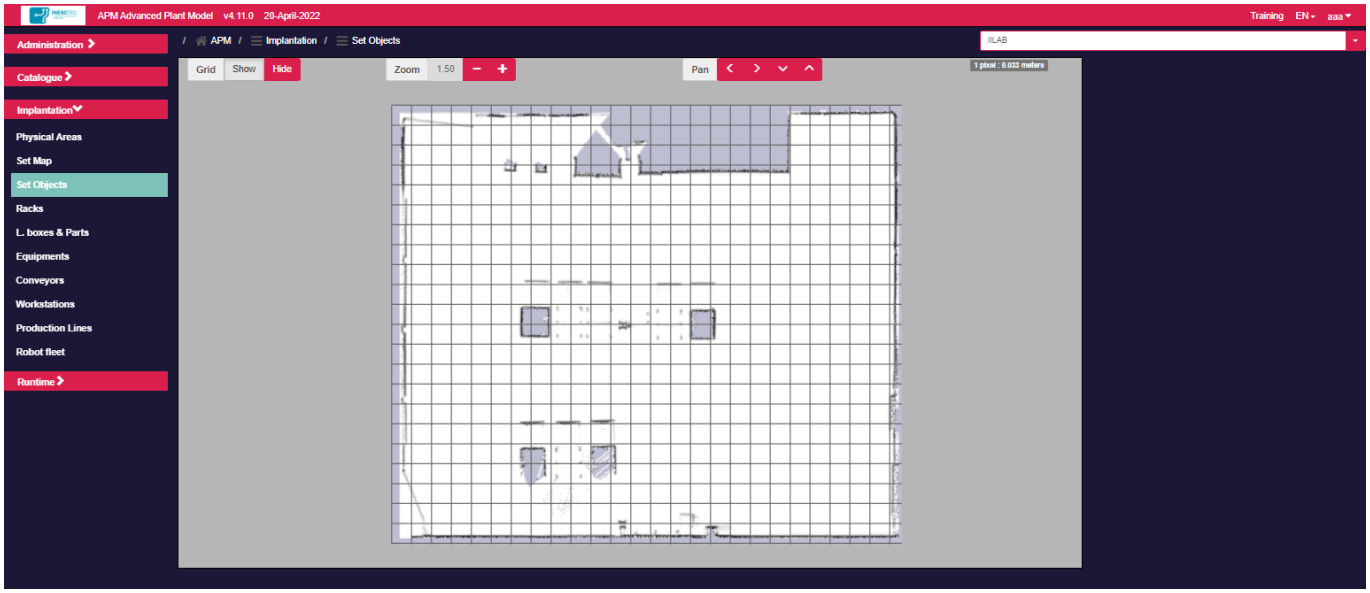
3. Confirm the creation of the physical area.



4. Select it so that you start modelling this new physical area (press the dropdown box on the top right).



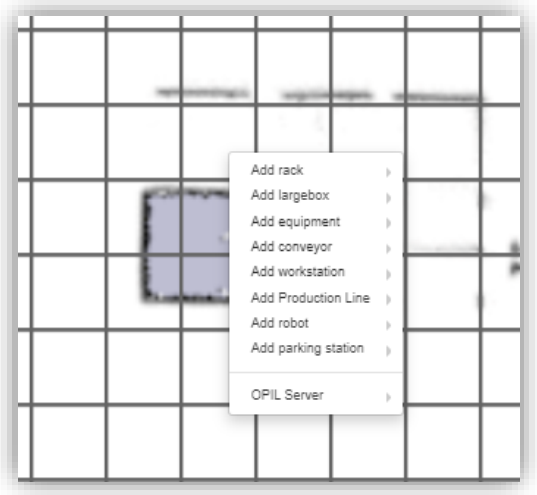
5. Go to **"Implantation / Set Objects"**. This is the place where you will implant objects on the Physical Area.



- The grid divides the area in squares of side length equal to one meter.
- You can zoom in or zoom out by pressing the Zoom button.
- You can move in the area by pressing the four Pan buttons.

The Model of a given Physical Area is built by selecting objects defined on the Catalogue and adding them to the Physical Area.

6. Pressing the right mouse button you'll get options that let you select an object from the Catalogue

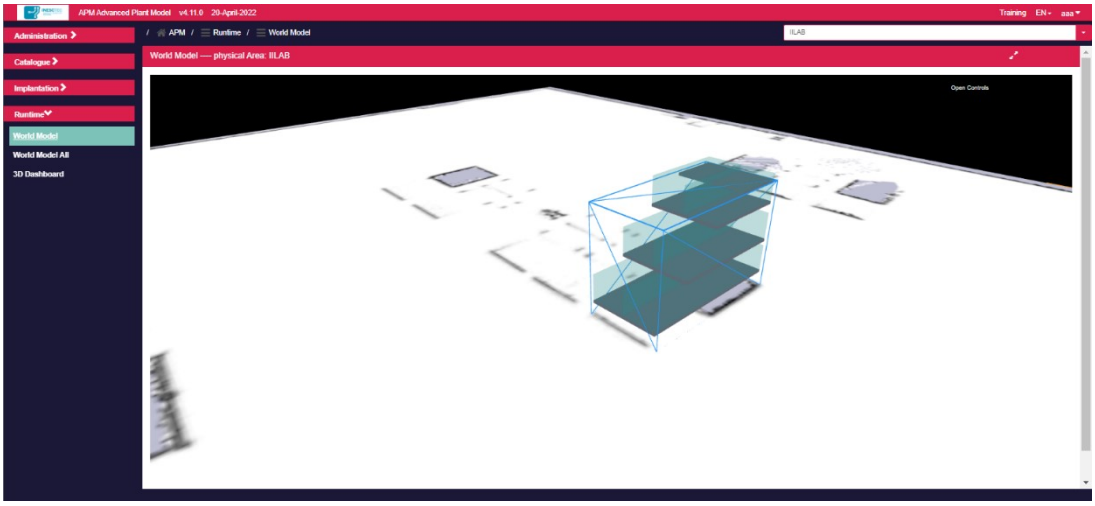


7. Select one of the objects (e.g. rack / TestSprint3 1410 x 2800), a red rectangle will appear in the working space

- You can now select the object and move it in the working area

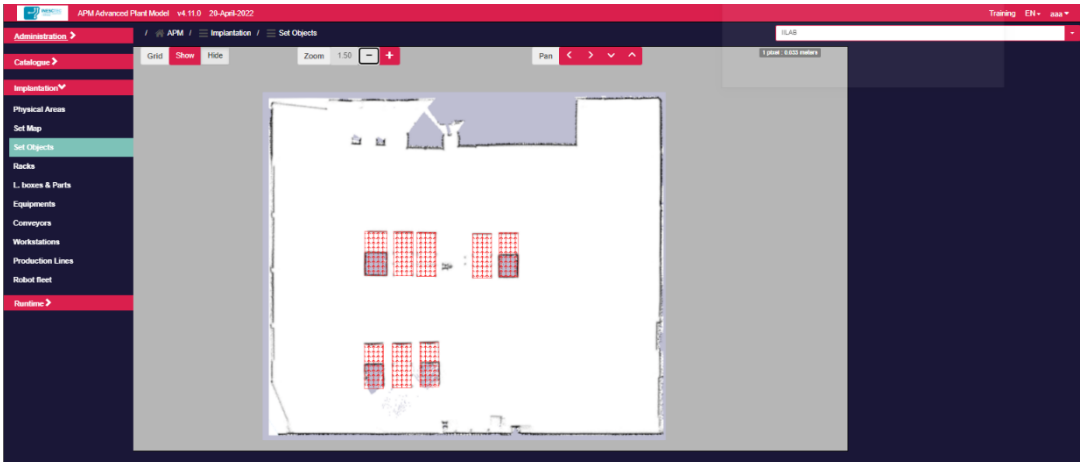
8. You can clone, rename, rotate, or delete the object by selecting it and pressing the right mouse button

9. Go to "**Runtime / World Model**", a 3D visualization of the Model created so far is shown

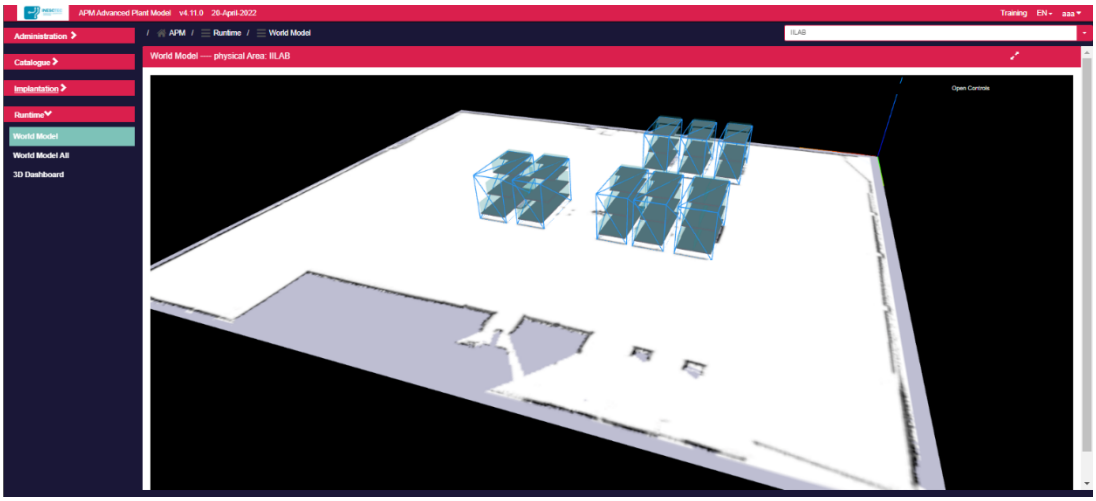


- You can zoom in and out by using the mouse wheel
- You can change the viewing perspective by selecting the left mouse button and moving the mouse around
- You can also press the right mouse button and move the mouse (image is shifted)

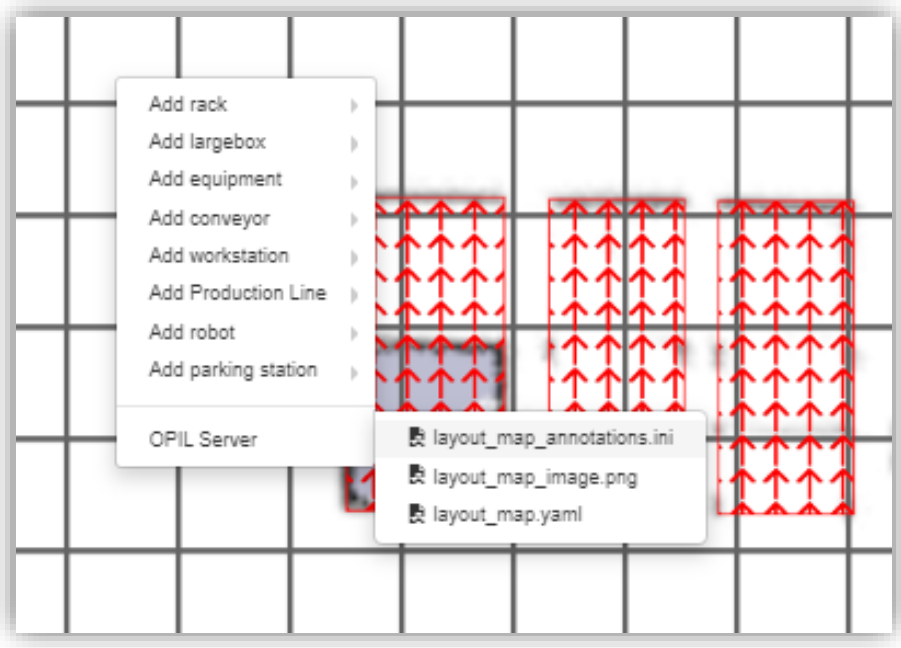
10. Go to **"Implantation / Set Objects"** and complete the digital representation of the Physical Area by instantiating more objects from the Catalogue (e.g. rack / TestSprint3 1210 x 2800).

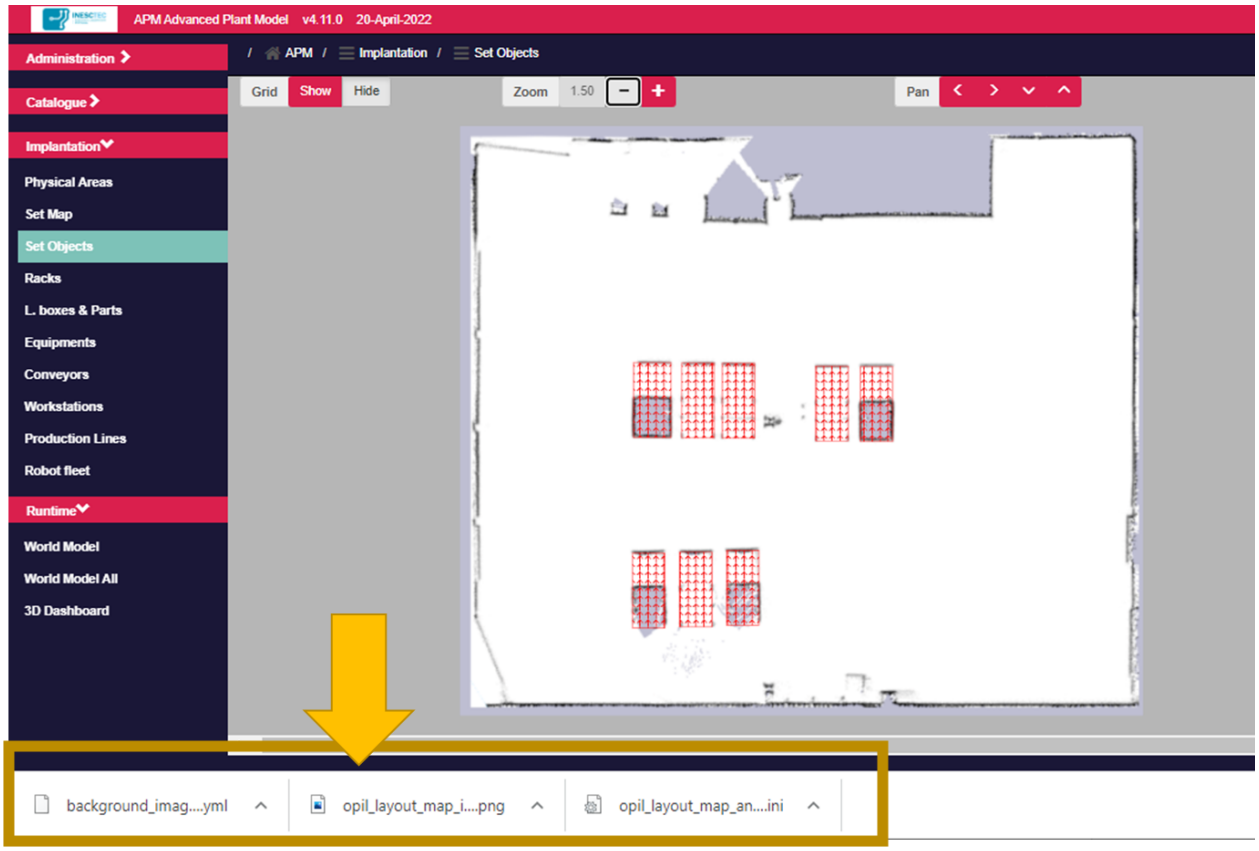


11. Go to **"Runtime / World Model"**, a 3D visualization of the Model created so far is shown



12. Go to **"Implantation / Set Objects"**. Generate the files that can be used by the OPIL server.
    - Press the right mouse button, expand the menu item "OPIL server" and you will get options that allow you to download the files *layout_map_annotations.ini*, *layout_map_image.png* and *layout_map.yaml*.





13. In this training example, the result will be as follows:
    - *opil_layout_map_annotations.ini*

opil_layout_map_annotations (4).ini

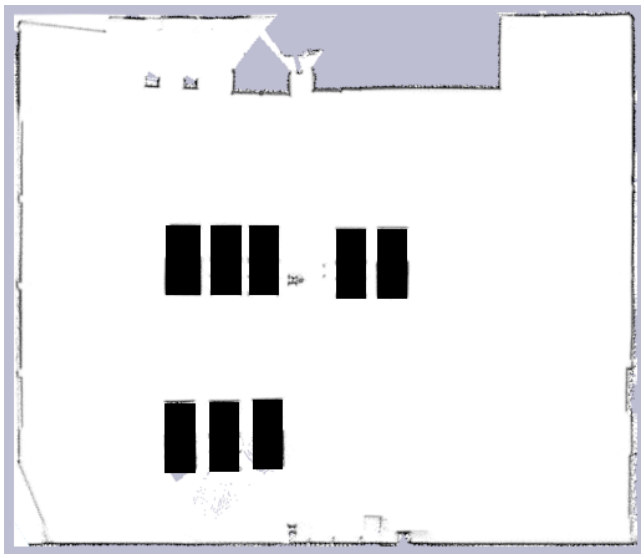
```
# annotations.ini file authomatically generated by the APM on 2022-04-29T11:53:30.580672200
[Rack.TestSprint3 1210 x 2800]
point_x = 10.59826086956521
point_y = 4.77673913043478
theta = 270.0
distance = 0.4

[Rack.TestSprint3 1210 x 2800]
point_x = 10.439999999999992
point_y = 11.777941176470584
theta = 270.0
distance = 0.4

[Rack.TestSprint3 1210 x 2800]
point_x = 15.61999999999999
point_y = 11.654999999999996
theta = 270.0
distance = 0.4

[Rack.TestSprint3 1210 x 2800]
point_x = 7.07652173913043
point_y = 4.668043478260868
theta = 270.0
distance = 0.4

[Rack.TestSprint3 1210 x 2800]
point_x = 8.83739130434782
point_y = 4.711521739130432
theta = 270.0
distance = 0.4

[Rack.TestSprint3 1410 x 2800]
point_x = 7.211764705882346
point_y = 11.810294117647057
theta = 270.0
distance = 0.4

[Rack.TestSprint3 1210 x 2800]
point_x = 13.93999999999999
point_y = 11.674999999999997
theta = 270.0
distance = 0.4

[Rack.TestSprint3 1210 x 2800]
point_x = 8.925294117647052
point_y = 11.792647058823526
theta = 270.0
distance = 0.4
```

    - *files layout_map_annotations.ini*

background_image.yml

```
# Authomatically generated by the APM on 2022-04-28T17:22:41.490940100
image: background_image.png
resolution: 0.05
origin: [0.0, 0.0, 0.0]
negate: 0
occupied_thresh: 0.65
free_thresh: 0.196
```

    - *opil_layout_map_image.png*



You can now transfer these three files to the OPIL computing environment and use them.

8.10 How to integrate the APM with the OPIL Server, part 2

As you have seen in Part 1, the APM lets you model a given manufacturing area and export the data in a format compatible with the OPIL server.

If you want to display the navigation of the robots controlled by OPIL in the 3D window of the APM, you will have first to install the APM in the same computational environment where you are running the OPIL Server. A binary version of the APM should be downloaded from the BetterFactory Github repository (https://github.com/ramp-eu/Advanced_Plant_Model) and installed in a docker-based environment (as instructed by the Github repository).

By default, the APM subscribes the following two entities on the ORION CB (Context Broker) of the RAMP IoT Platform:

- id: map type: ROBOT
- id: robot_opil_v2 type: ROBOT

The APM has the following behavior:

- OPIL Messages are processed in the context of the 'OpilArea' physical area. This name is pre-defined in the APM. When generating the digital artifacts for OPIL (part 1 of this tutorial) you should name the physical area as 'OpilArea'.
- The 'map' message coming from the ORION CB is processed by the APM but the Tool doesn't do anything with the contents of this message.
- Messages from the robots are processed and the APM expects two JSON fields to be in the message: **current_motion** and **robot_description**. These are used to update the localization of the robot in the 3D area and to set the geometric dimensions of the robot.
- The APM instantiates a robot on the first message coming from a robot through the Orion CB. The robot type with the same name is used in the instantiation of the robot in the 3D Model.

Thus, you should do the following on the APM's user interface:

1. Create a Physical Area with the name **OpilArea**. You should follow the same steps as in the part 1.

   The APM will associate the messages coming from the ORION Context Broker with this area.

   If you don't do this, messages coming from the ORION Context Broker are simply ignored.

2. Create a robot of type 'Robot.AGV' with the same name as the one used by OPIL.

   In the default configuration, there is one OPIL robot: **opil_robot_v2**. If this is the case, you may associate a CAD model to the robot type so that you have a more realistic visualization of the root in the APM user interface.

9 Conclusions

This report addresses the Digital Twin Designer, an element inside the Advanced Plant Model, that enables a person responsible for the production to build and maintain a digital representation of the physical environment available in a given manufacturing or logistics area. Physical objects such as logistics racks, logistics pallets, work stations, robotic manipulators and equipment in general can be represented by implanting their 3D models on top of a 2D map representing the target area. By following a simple working methodology, users in a Manufacturing SME can build the Model and use the tool to show three-dimensional perspectives of the factory floor.

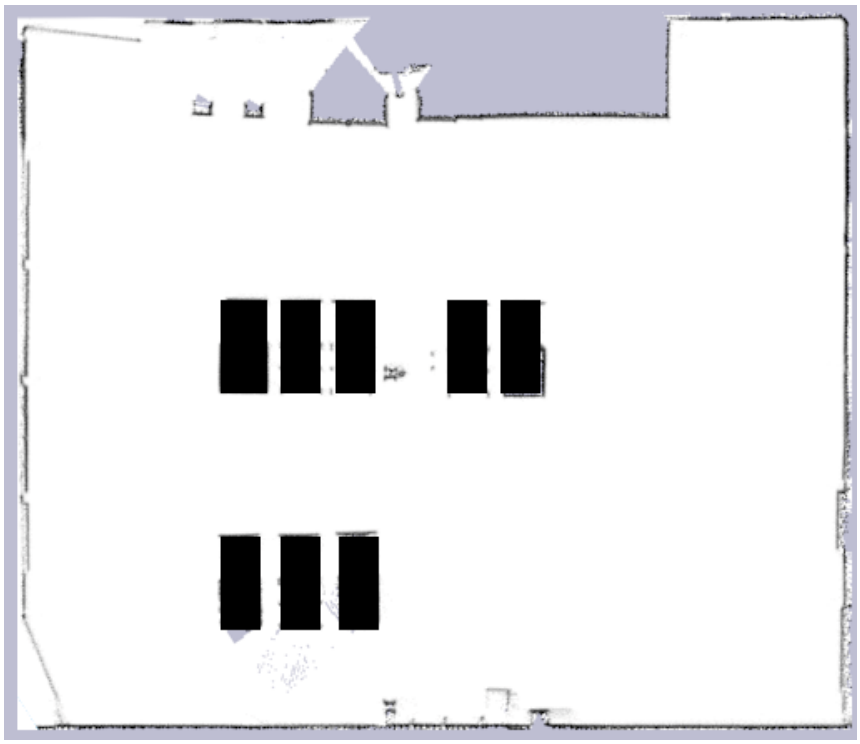
Significant work accomplished during the first year of the project had the main goal of enriching and preparing the Digital Twin Designer to be included in the co-creation space of the RAMP Marketplace. The use of the Tool in the context of the first KTEs validated the approach and allowed the authors to detect and improve some inconsistent behaviour. Furthermore, the Tool has been integrated in the Better Factory Advanced Production Planning and Scheduling (APPS) system, enriching the functionality of the Production Reconfiguration and of the Logistics Automation and Optimization packages. As part of this work, technical integration of the APM with the RAMP IoT Platform was accomplished by using the OSPS data messages as a basis.

A user manual is provided in this report as well as a set of training material which guide the user on the way to use the Tool.

10 Annex A

This annex provides samples of OPIL layout artefacts.

Sample of a '.png' file generated for the OPIL solution:



Sample of a '.yml' file generated for the OPIL solution:

```
# Authomatically generated
# by the APM on 2022-03-24T12:12:03.629240700
image: background_image.png
resolution: 0.05
origin: [0.0, 0.0, 0.0]
negate: 0
occupied_thresh: 0.65
free_thresh: 0.196
```

Sample of 'annotations.ini' file generated for the OPIL solution:

```
# annotations.ini file authomatically generated
# by the APM on 2022-03-24T12:44:42
[Rack.Rack6]
point_x = 7.1
point_y = 4.725
theta = 270.0
distance = 0.4

[Rack.Rack7]
point_x = 8.9
point_y = 4.725
theta = 270.0
distance = 0.4

[Rack.Rack8]
point_x = 10.65
point_y = 4.725
theta = 270.0
distance = 0.4

[Rack.Rack1]
point_x = 7.2
point_y = 11.825
theta = 89.99999999998818
distance = 0.4

[Rack.Rack2]
point_x = 8.9
point_y = 11.825
theta = 89.99999999998818
distance = 0.4

[Rack.Rack3]
point_x = 10.55
point_y = 11.825
theta = 89.99999999998818
distance = 0.4

[Rack.Rack4]
point_x = 13.9
point_y = 11.825
theta = 89.99999999998818
distance = 0.4

[Rack.Rack5]
point_x = 15.5
point_y = 11.825
theta = 89.99999999998818
distance = 0.4
```

11 Annex B

This annex provides samples of OPIL ROS messages.

Sample of a ROS current_motion message:

```
# TOPIC: /robot_opil_v2/current_motion
# MESSAGE: mars_agent_physical_robot_msgs/Motion
---
current_position:
  header:
    seq: 0
    stamp:
      secs: 2463
      nsecs: 500000000
    frame_id: "/map"
  pose:
    position:
      x: -5.38133055038
      y: -4.20080015791
      z: 0.0
    orientation:
      x: 0.0
      y: 0.0
      z: 0.999999321375
      w: 0.00116501020344
current_velocity:
  linear:
    x: 0.0
    y: 0.0
    z: 0.0
  angular:
    x: 0.0
    y: 0.0
    z: 0.0
```

Sample of a ROS robot_description message:

```
# TOPIC: /robot_opil_v2/robot_description
# MESSAGE: mars_agent_physical_robot_msgs/RobotAgentProperties
---
robot_id:
  uuid: [0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 1]
  description: ''
type:
  vehicle_type: 0
footprint:
  header:
    seq: 0
    stamp:
      secs: 0
      nsecs: 0
    frame_id: ''
  polygon:
    points:
      -
        x: 0.34999999404
        y: 0.25
        z: 0.0
      -
        x: -0.34999999404
        y: 0.25
        z: 0.0
      -
        x: -0.34999999404
        y: -0.25
        z: 0.0
      -
        x: 0.34999999404
        y: -0.25
        z: 0.0
min_height: 0.38299998641
max_height: 0.38299998641
payload: 0.0
max_pos_x_vel: 1.10000002384
max_neg_x_vel: 1.10000002384
max_pos_x_acc: 0.5
max_neg_x_acc: 0.5
max_pos_y_vel: 0.0
max_neg_y_vel: 0.0
max_pos_y_acc: 0.0
max_neg_y_acc: 0.0
max_pos_ang_vel: 1.10000002384
max_neg_ang_vel: 1.10000002384
max_pos_ang_acc: 0.5
max_neg_ang_acc: 0.5
velocity_control_sensitivity: 1.0
min_turning_radius: 0.0
batt_capacity: 1.0
batt_max_voltage: 1.0
weight: 0.0
vendor: "default"
action_capability: []
```

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