Artificial Intelligence for supporting Maritime Terminal Management, Safety and Security

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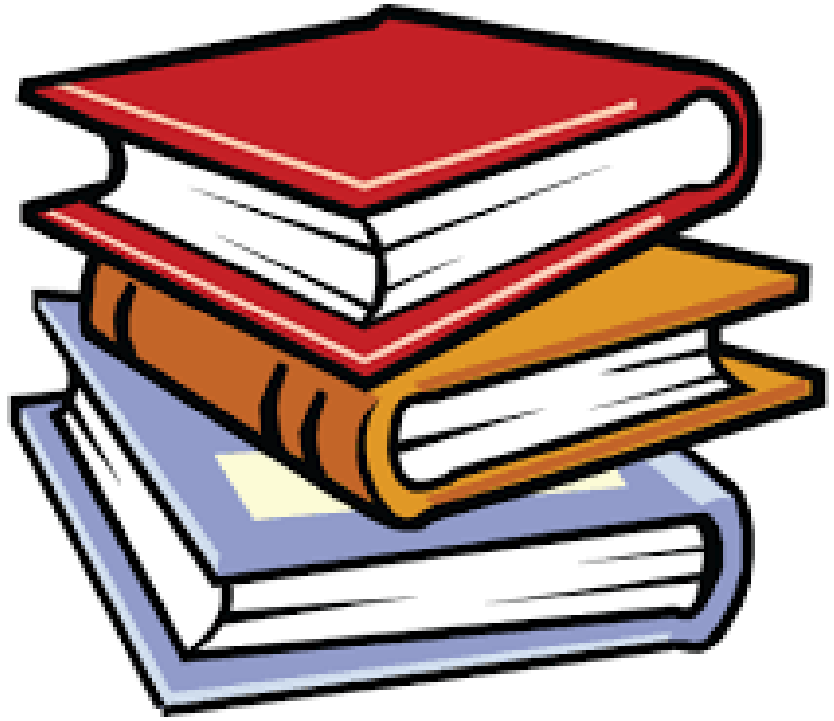
Literature Review

- In the recent year, the international scientific literature highlighted the importance that cyber-physical systems will increasingly assume within all the production systems and business processes.
- Gamer et al. provided an interesting taxonomy in which both the historical role of industrial automation systems and their evolution in autonomous systems that can independently learn to make better and better decisions in relation to the processes they manage



Literature Review

The enabling technologies of this process are constituted precisely by:

- **Sensors** that must be increasingly connected and able to supply their own power (e.g. harvesting techniques) [*Damiani et al.*, *Sudevakayam et al.*, *Mladenov et al.*],
- **Fast connectivity** offered by 4G and 5G [*Burke et al.*]
- **Integration** with operational databases such as ERP systems [*Tantik et al.*]
- Creation of **Digital Twins** of real systems with high degree of fidelity [*Briano et al.*]
- **Cognitive abilities** to perceive, understand, and finally solve complex problems by choosing alternatives making the best decisions [*Brown et al.*]

Literature Review

Some applications of the above technologies found in the literature are:

- *Morra et al.* introduced a Digital Twin based on System Dynamics simulation in order to perform a predictive analysis on a short time period based on the energy consumption management. This model helps choosing the best time period for buying electricity. The study has been implemented in the container terminal of an Italian port
- Another study still based on the same harbor has been carried out by *Briano et al.* and it shows a Decision Support System in which a System Dynamics simulation describes the port activities. The system is integrated with an ERP system in order to receive real-time data, allowing also a what-if analysis to support the decision-making process
- *Bruzzone et al.* showed an interesting work based on simulation in a port environment. This work aims to introduce a ‘a priori’ risk analysis supported by simulation to evaluate the related environmental impact.

Port Services – Automation and integration levels

- **Level 3:** the port is equipped of a control room with cyber-physical systems able to react autonomously, suggesting to the operator a series of actions in response to the event generated by the decisional model based on the port digital twin and a artificial intelligence system in which the human must take as final decision the acceptance or modification of the proposed action.
- **Level 4:** it includes the system full control based on artificial intelligence and the human action only if the decision made would exceptionally reveal wrong.
- **Level 5:** this might be adopted based on some and well-defined cases. It involves the full autonomy of the decisional process, even in human absence. Such scenario could be adopted for decision in which the action rapidity is pivotal, such as the implementation of the evacuation plan in case of emergency and the activation of the emergency teams and first aid.

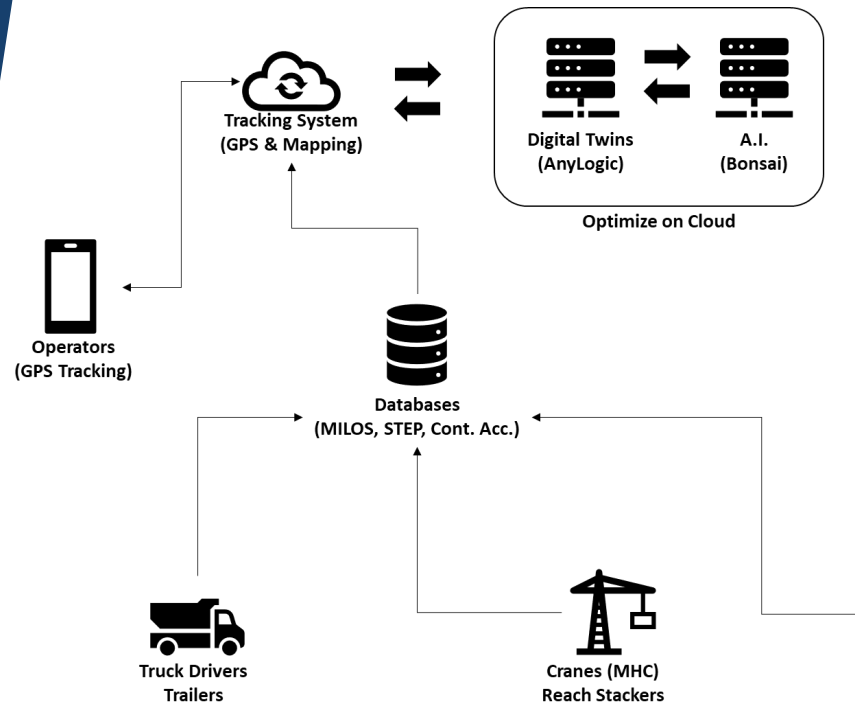
Case - Study: Evacuation

Possible scenarios such as fire propagation, explosion etc. can be implemented through **simulation**. Furthermore, the interaction among these scenarios with the evacuation phases of people can be implemented.

Artificial intelligence implemented in the digital model is able to analyze the simulation through **machine learning**, and can:

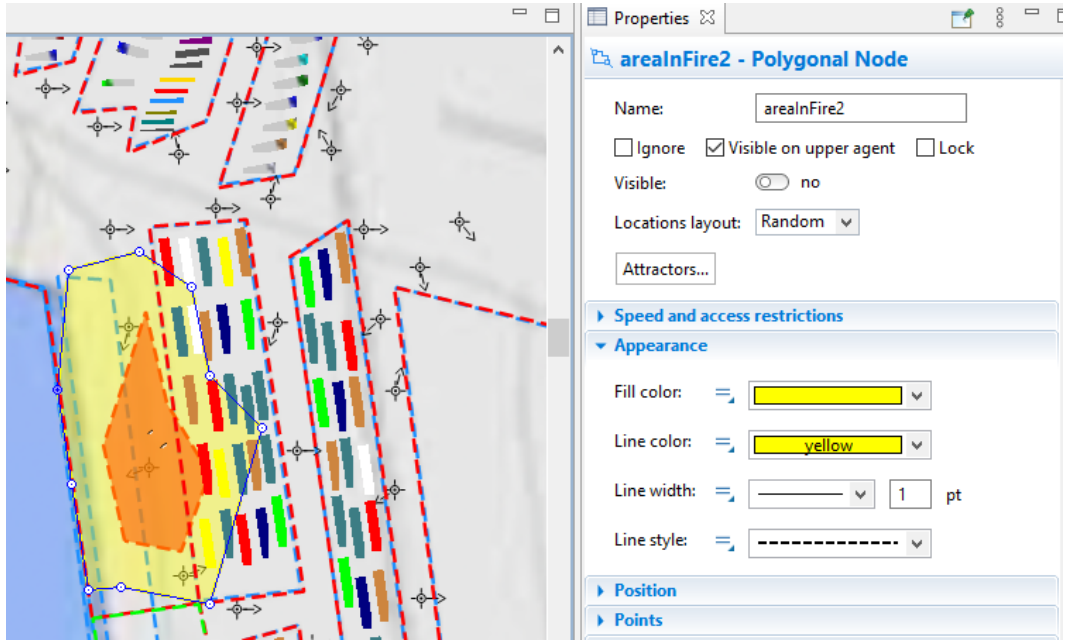
- Determine which are the optimal evacuation paths

- Assign each person, based on the registered location, a safe place by communicating it with a notification that arrives on the subject's mobile phone.



TEBETS FEATURES

- Operators Safety Tracking (GPS)
- Container Yard Tracking (DT)
- Trailer Parking Tracking (DT)
- Drivers Tracking (DT)
- Reach Stackers Position Tracking (GPS)
- Tractors Position Tracking (GPS)
- Ships Handling Tracking (DT)
- Yard Optimization (AI)
- Operations Optimizations (AI)
- Emergency Procedures Supervision (AI)
- Traffic Yard Management (AI)
- Emergency Broadcasting Messages (AI)
- Turnstile Control (DT)
- Safety Area Management (DT)



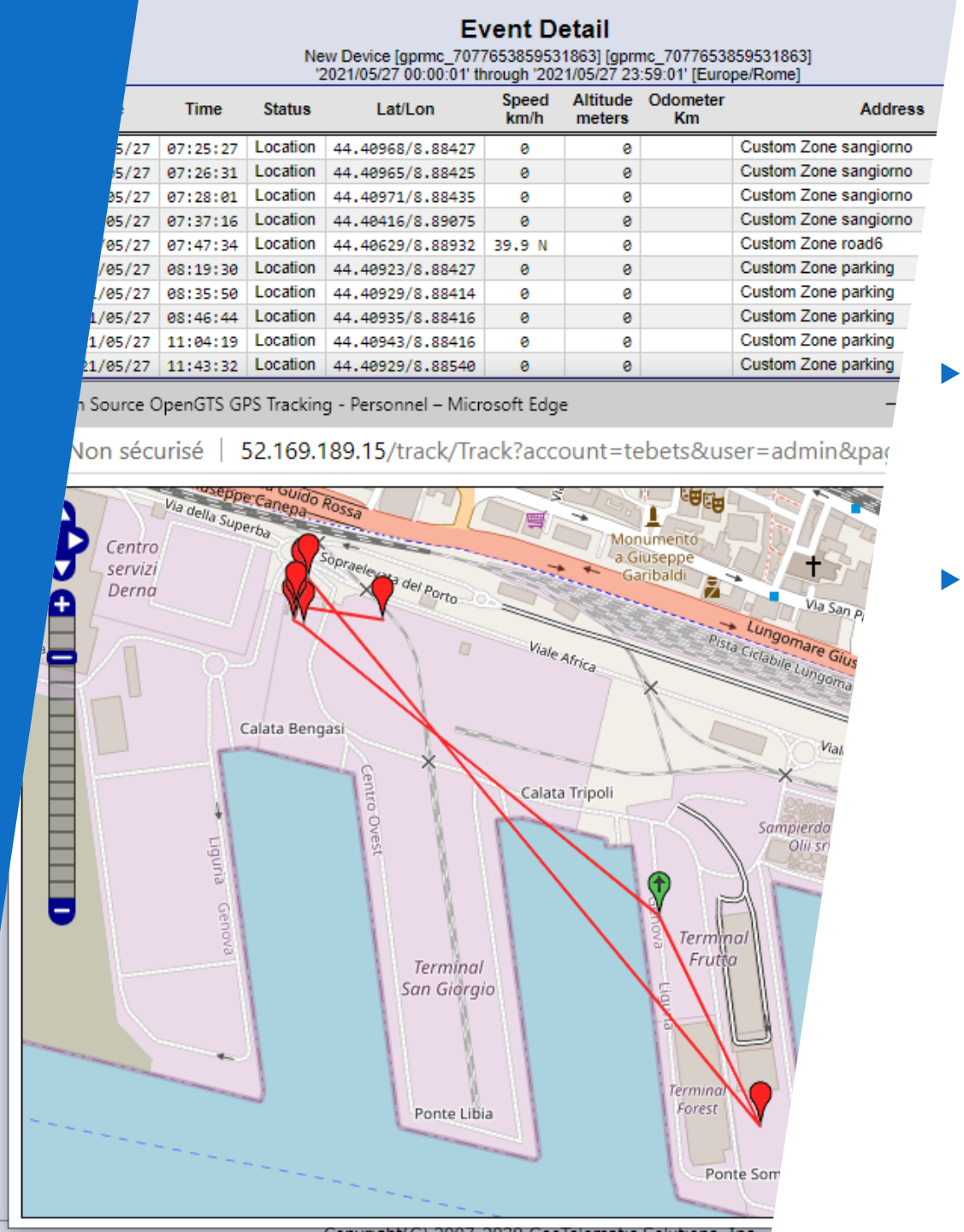
Case – Study: Evacuation

If the sensors detect an anomaly, such as an accident/fire in a particular portion of the terminal. This is immediately communicated to the computer systems connected in the control room.

Through the **digital model** the location where the fire occurred and the materials that are stored nearby is evaluated.

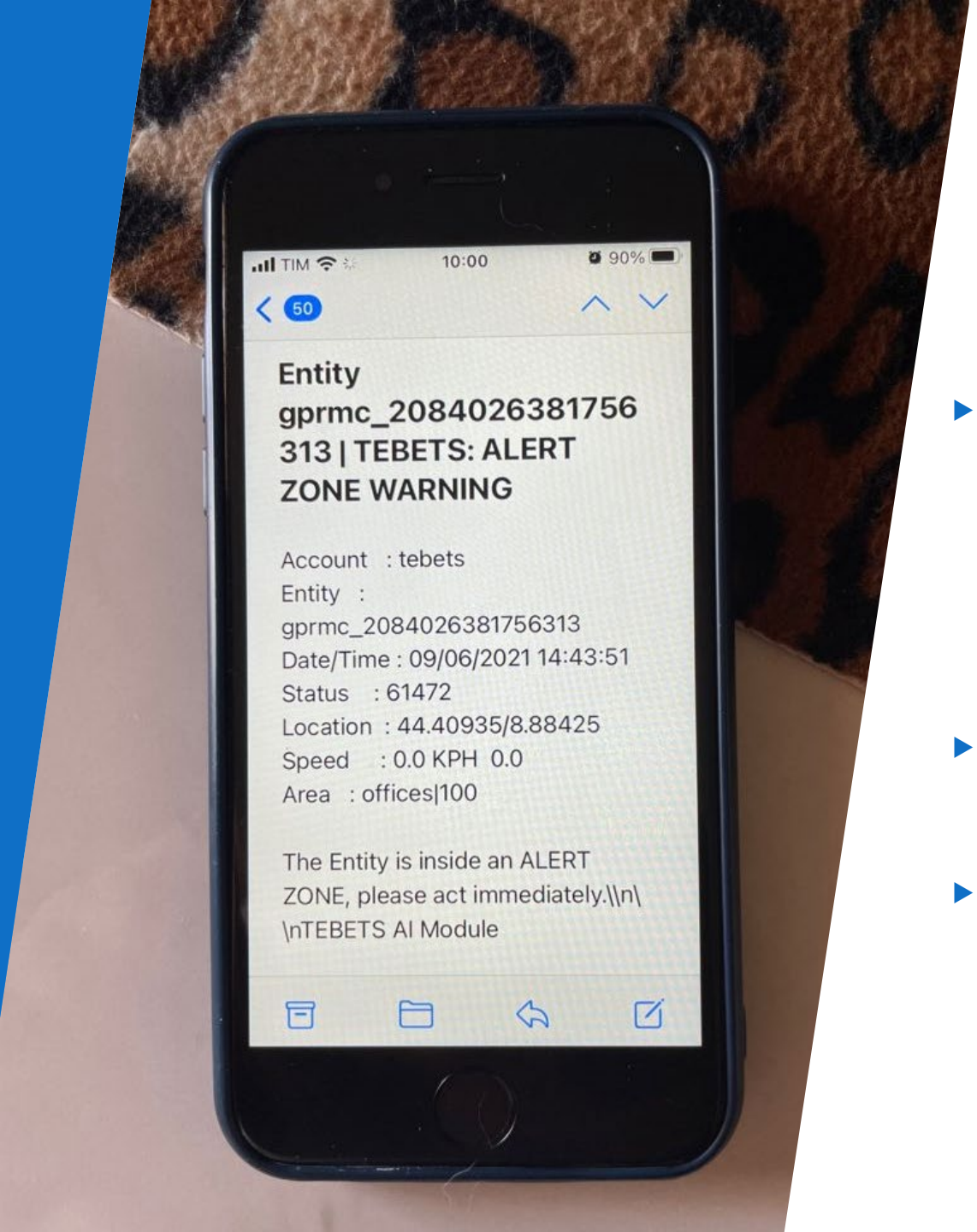
Thanks to the proposed system it is possible to know:

- Exact location of the people in the port;
- Data from all the arriving and departing ships and their loads;
- Data from all the arriving and departing trucks/trailers and their load.



Case Study: "TSG Trailers & People Safety"

- The TEBETS technological demonstrator was built using a modular architecture that included three main components (Systems):
  - the tracking system of the entities present in TSG,
  - the DT of Port Operations and iii) the Platform for AI services.
- Within the Technological Demonstrator some data sources have been identified which can be summarized in the following:
  - Access control: the subsystem allows to have the access data (check-in and check-out) of all the drivers who enter and leave the TSG through one of the gates, in this way the people who are inside the TSG area are traced.
  - MILOS and STEP systems: these systems provide all the information relating to the movement of goods and to the movement of containers and trailers both in import and export.
  - Vehicle tracking systems: this system plans to monitor the position of some vehicles (Reach Stacker and Tractors) every five minutes.
  - Operator Tracking System: this system includes a smartphone app (iPhone and Android) that communicates with a tracking system Servlet and monitors the position (with an update frequency every ten seconds) of each operator equipped with this device.



"TSG Trailers & People Safety" Connecting Data (IOT & ITTT)

- Data acquisition system from devices: the system also allows to acquire specific data from distributed sensors via WiFi / GPRS / LTE data connection. In general, the following data can be managed for each device:
  - AtmosphereFieldInfo
  - ThermoFieldInfo
  - AnalogFieldInfo
- Temperature measurement device: In order to face and prevent COVID-19, every person is subject to temperature measurement before accessing the port.
- Alerting system: this system allows to communicate with operators through certain channels such as emails and SMS messages. This possibility is provided to be able to contact operators and provide them with information relating to relevant procedures and events within the terminal. The system has a rules engine with which it is possible to activate a series of messages according to the status of the areas

Case Study: “TSG Trailers & People Safety”

In the scenario considered, Bonsai was used as a Reinforced Learning system coupled to a Digital twin of the TSG which implemented the trailer import and export procedures.

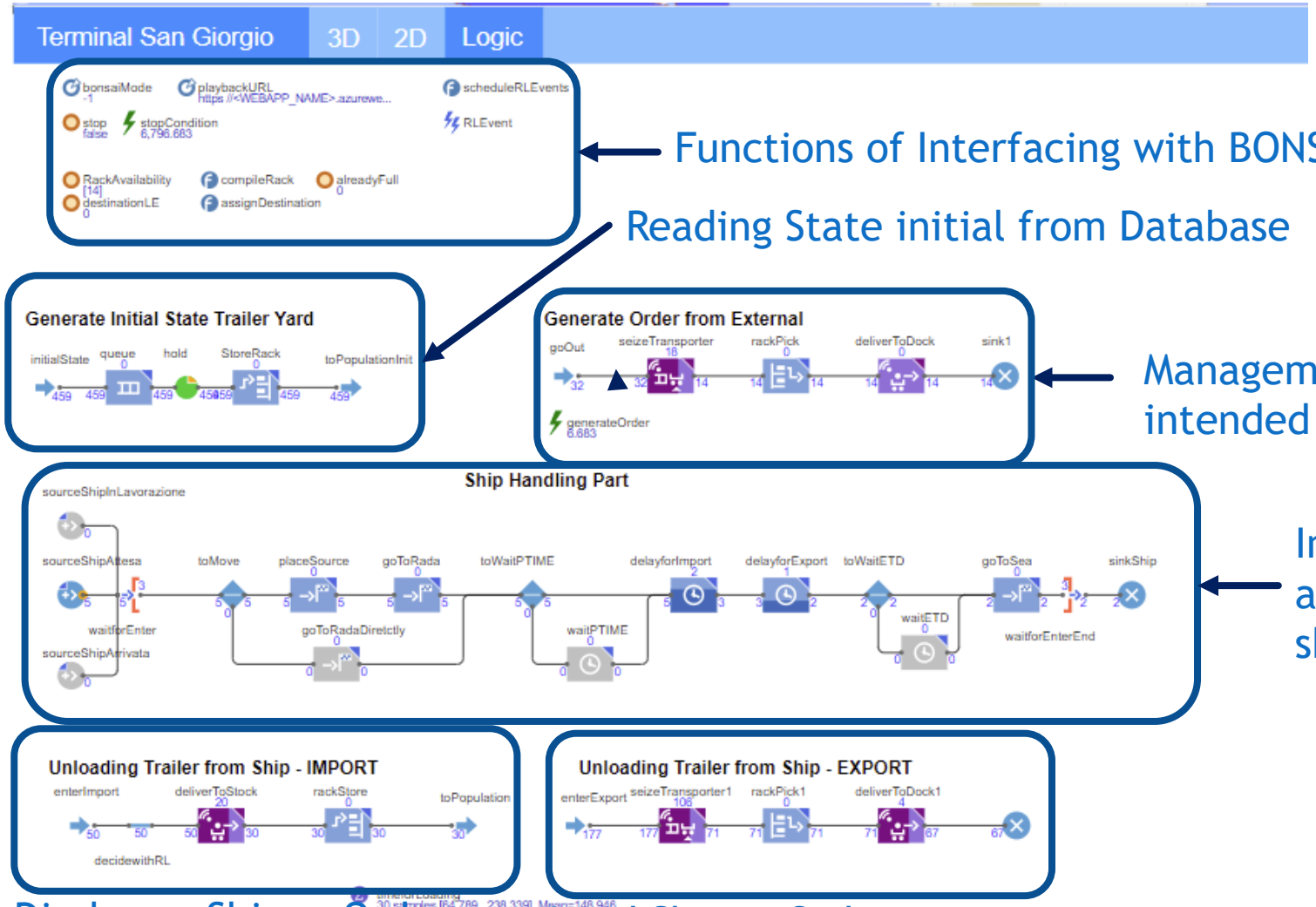
The objective function chosen for training the Bonsai "Brain" was implemented as the minimization of process times by assigning the various trailers to the parking areas in order to make boarding and disembarking operations more fluid.

The data set was therefore made up of real data updated continuously every 5 minutes which allowed for training sessions based on realistic scenarios.

In particular, Bonsai is used in the phase of assigning the parking area, effectively creating an optimization function for the use of the parking areas. Each trailer therefore, depending on the current conditions of the terminal, receives a proposal for allocation in one of the 17 parking areas in order to optimize the objective function.

Obviously, the system will continue to learn from the simulations and the current state of the TSG, creating a real autonomous decision-making cyber-physical system as envisaged by the TEBETS project proposal.

“TSG Trailers & People Safety”



Functions of Interfacing with BONSAI

Reading State initial from Database

Management orders import, intended to go out

Interfacing with Database and managements arrive ships.

Discharge Ships - Orders IMPORT

Load Ships - Orders EXPORT

Interface BONSAI

Brains ⇅ + Create brain

TrailerBrain-AUTO

TrailerBrain

v07

v06

v05

Show more

Simulators + Add sim

TrailerSimulation

TrailerBrain / v07 | Teach | Train

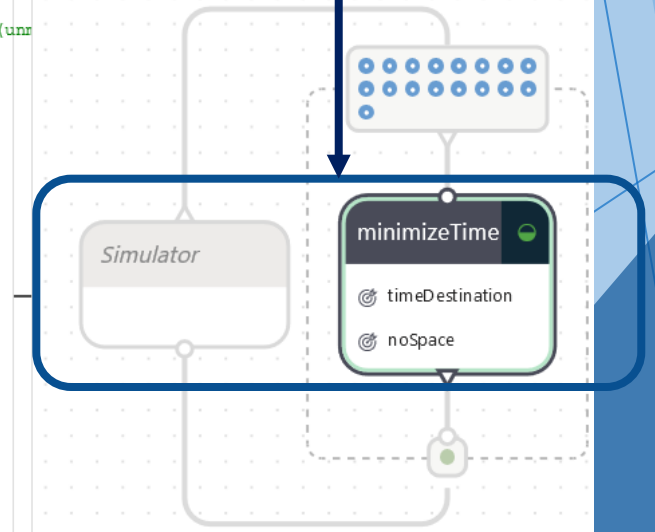
Train

Reading State Simulation

```
inkling "2.0"
using Number
using Math
using Goal

# Define a type that represents the per-iteration state
# returned by the simulator.
type SimState {
    tempoMedio: number,
    RackPositioning: Number.Float32[14] ,
    tempoDeviazione: number,
    alreadyFull: number,
}

# Define a type that represents the per-iteration action
type SimAction {
    Destination: number <0 .. 14 step 1>,
}

simulator Simulator(action: SimAction): SimState {
    #Togliere il commento seguente se non si vuole avviare il simulatore in locale (unm
    #package "TrailerSimulator"
}

# Define a concept graph
graph (input: SimState): SimAction {
    concept minimizeTime(input): SimAction {
        curriculum {
            source Simulator
            goal (s:SimState) {
                minimize timeDestination: s.tempoMedio in Goal.Range(140,180)
                avoid noSpace: s.alreadyFull in Goal.RangeAbove(1)
            }
        }
    }
}
```

Space of Action

connection Simulation



Training concept

Conceptual Model- BONSAI

SYSTEM STATUS:

- Average time of transport of the Trailer from ship to destination choice;
- Deviation standard of the distribution gods times medium of transport;
- Number of places available in every area of the yard;
- Parameter of control of feasibility of the solution proposal;

AREA OF ACTION:

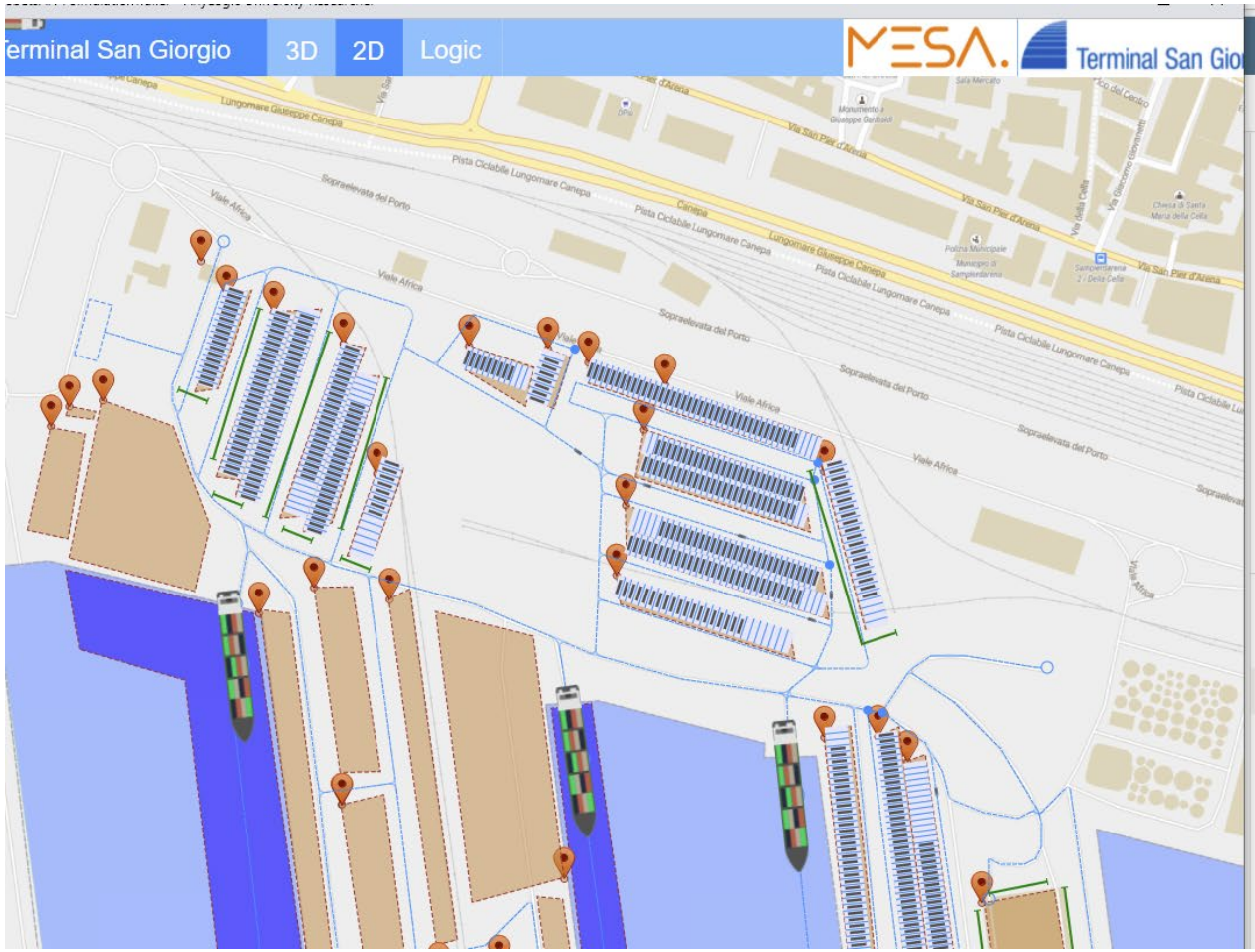
- Upon arrival of an new Trailer from download from ship, intelligence artificial needs to to assign a destination in terms of area;

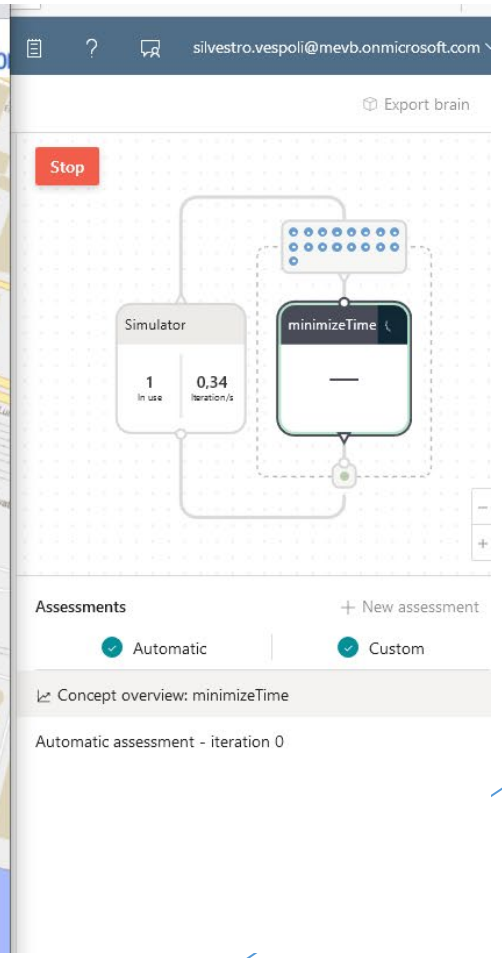
AIMS:

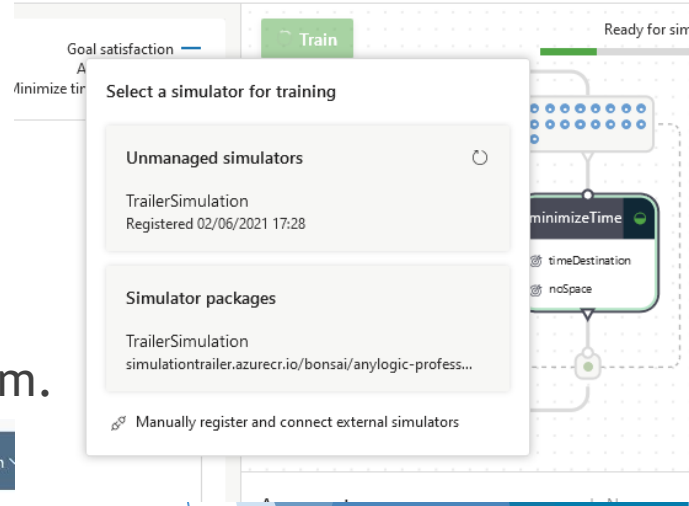
- Minimize the Average time of transport of the Trailer;
- To avoid of to assign a workstation that she has not availability;

AI Training

BONSAI he takes the control of the template ed it begins to to stalk the aims required, doing reference to state of the system time in time transmitted to him.

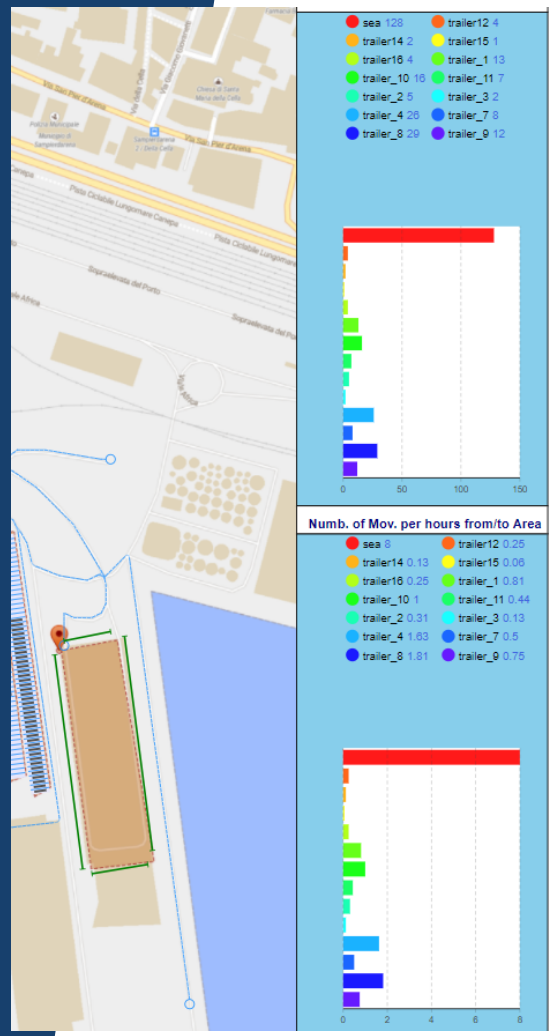


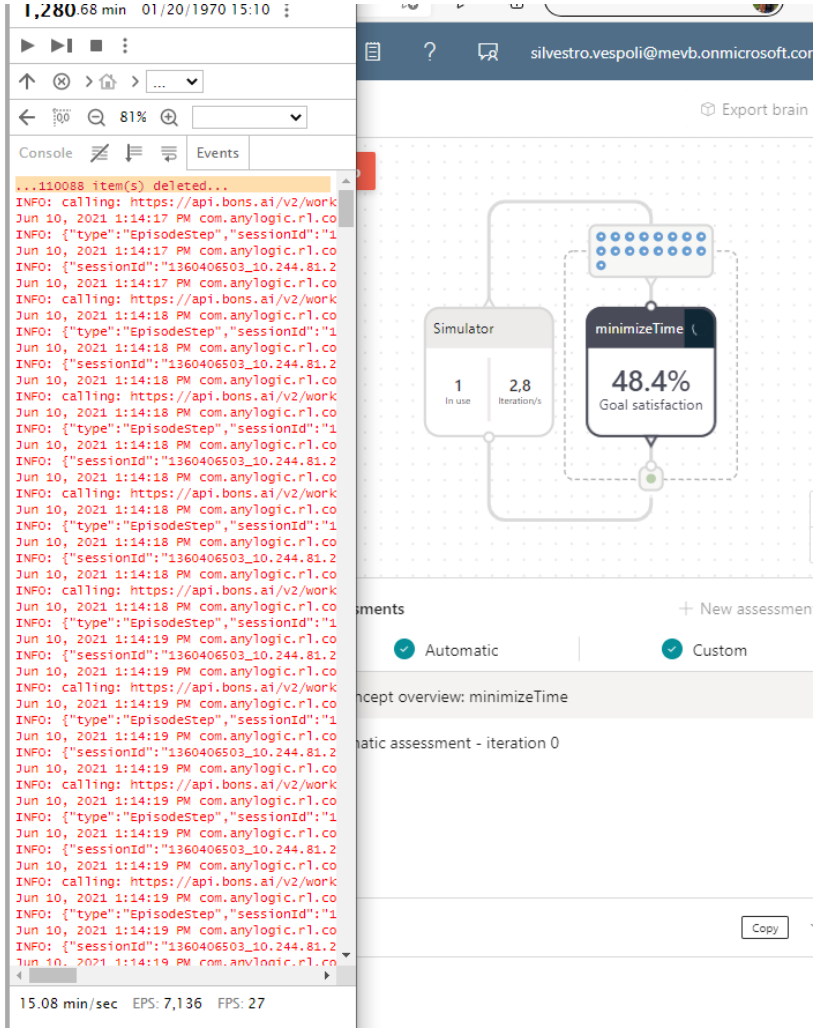




AI Training

- BONSAI he takes the control of the template ed it begins to to stalk the aims required, doing reference to state of the system time in time transmitted to it.
- Training achieved a 20% performance improvement.

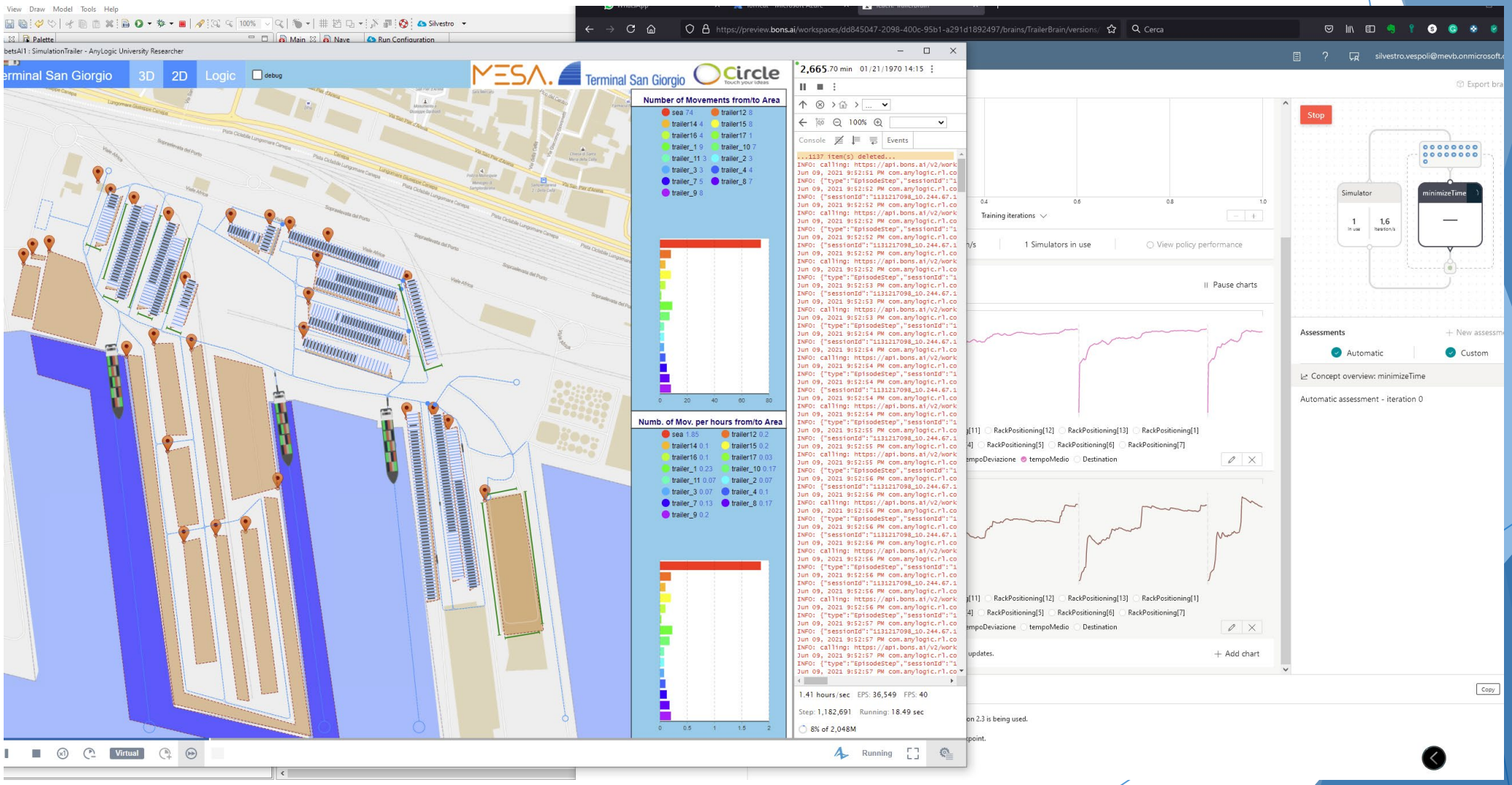




Results achieved

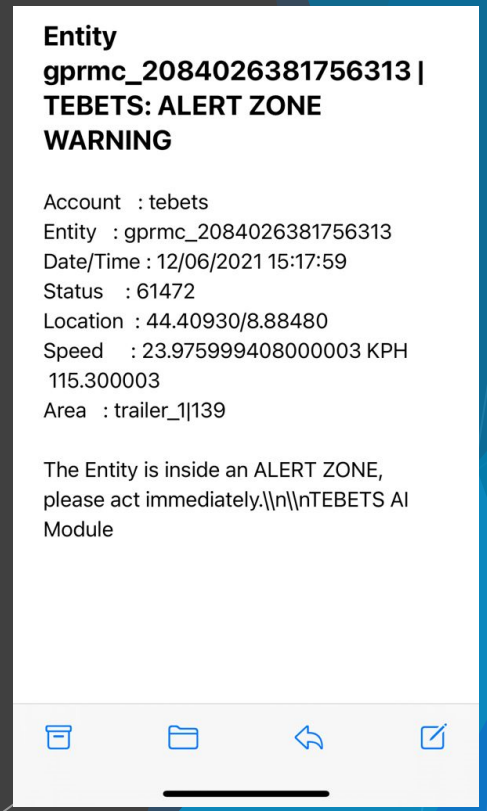
- After the training, the neural intelligence was shown to assign which position of the Trailer, positions close to the ship's arrival bay:
- For example, for the ship landing on the left, the T1, T2, T3 and T4 locations are preferred, while for the ship that landed in the center, the central locations T7, T8, T9 are preferred; in the same way for the ships docking on the right, which prefer the stations further to the right, near the Fruit Terminal.
- Consequently, there were shorter average transport times necessary for the transport of the Trailer from the ship to the Yard, with the same number of orders managed, the fleet of Trolleys and their speed and acceleration parameters;

Feedback to the System



Feedback for Operators Safety

- At the same time, the simulation of the port process leads to the definition of the expected movements on the various areas of the terminal and therefore to the possibility of determining dynamic “traffic” conditions on the individual areas.
- One of the Digital Twin's feedback is therefore a level of “congestion” of each area that is transmitted to OpenGTS and used by it for its Engine Rule in order to implement that decision-making process defined by level 4 of port automation.
- Thus, if in one of the areas of the TSG the presence of vehicles for delivery or collection of trailers is foreseen which may involve an increased risk of collision between vehicles (eg reach stacker) the area itself is identified as "dangerous" modification of a parameter in the OpenGTS database (geozone table).



Conclusions

- The objective of the TEBETS project was to design an intelligent surveillance system (e.g. an industrial operational security control room) for the flow of people and vehicles in a port using interconnected sensors in order to share information with operations management in Real-Time.
- The data capture system was designed from actually installed utilities (surveillance cameras, sensors, etc.) and updated with new devices and systems connected with IT systems.
- Surveillance areas include people's paths inside the terminal, security checkpoints, tracking the locations of people and vehicles.