This project has received funding from the European Union's Horizon 2020 research and innovation programme under grant agreement No 861111

Ref. Ares(2022)3970744 - 27/05/2022

Drones4Safety

Research & Innovation Action (RIA)
Inspection Drones for Ensuring Safety in Transport Infrastructures

Virtual Inspection Module

D4.3

Due date of deliverable: 31.5.2022

Start date of project: June 1st, 2020

Type: Deliverable
WP number: WP4

Responsible institution:
Delair/ALTEIA

Editor and editor's address:
Nicola Luminari (nicola.luminari@alteia.com)
Paolo Guzzini (paolo.guzzini@alteia.com)

This project has received funding from the European Union's Horizon 2020 research and innovation programme under grant agreement No 861111

Version 1.0 FINAL
Release Date: May 30th, 2022

Project funded by the European Commission within the Horizon 2020 Programme		
Dissemination Level		
PU	Public	✓
CO	Confidential, only for members of the consortium (including the Commission Services)	

Change Log

Rev.	Date	Who	Site	Change
1	30/05/2022	Paolo Guzzini Nicola Luminari	DL	Final Version

1. Executive Summary

This document describes the software platform adopted to display the digital twin of the structures analyzed within the context of the Drones4safety project (i.e., bridges and railways).

Originally the task 4.4 connected to this deliverable aimed at developing from scratch a new software tool able to:

- display 2D data (images with detected defects)
- display 3D data (3D models obtained either with photogrammetry or Lidar) and navigate over the model
- measure data in 2D and 3D

The development part of this task 4.4 was finally de-scoped as a consequence of the availability, thanks to Alteia (Delair's spin off created in 2020 in order to offer enterprise solutions of visual intelligence AI based), of a web platform capable of overmatching the original task's requirements.
The Alteia platform, is an easily deployable platform for rapidly integrating, managing and securing visual data and has been proposed as official tool for ingesting and managing Drones4safety visual data.

A free account for viewing data has been created for all project members.
For accessing the platform, please refer to [RD-3]

The platform's architecture is based on 3 main pillars:

- FUSE: **capability to combine data** in a unique repository and navigate 2D and 3D datasets;
- BUILD: **accelerate the development** of AI-based applications;
- DEPLOY: capability of **deploying AI applications** that seamlessly work with existing data storage, enterprise source systems, tools, and underlying infrastructure.

A specific data repository for the project has been created inside the Alteia Platform: it is named **Drones4safety.**
The data structure inside the Alteia Platform is according the following architecture

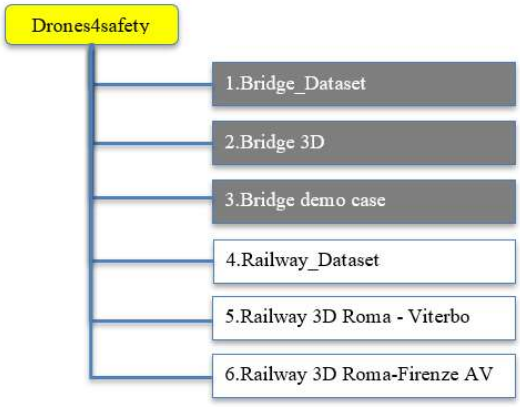

Figure 1: data structure in Alteia platform for the Drones4safety project

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Acronyms

Acronym	Description
API	Application Programming Interface
AWS S3	Amazon Web Services (AWS) Simple Storage Service (S3)
D4S	Drones for Safety
EGNOS	European Geostationary Navigation Overlay Service
GNSS	Global navigation satellite system
SDK	Sofware Development Kit

Explanations for H2020 terms can be found in the funding and tenders glossary: https://ec.europa.eu/info/funding-tenders/opportunities/portal/screen/support/glossary

Definitions

In the following, the definition of some terms used in the document is provided.

Term	Description
Apache Kafka	Apache Kafka is an open-source distributed publish-subscribe messaging platform that has been purpose-built to handle real-time streaming data for distributed streaming, pipelining, and replay of data feeds for fast, scalable operations.
Data Build	The capability to accelerate the development of AI-based applications via different tools.
Data Fuse	A capability that enables to integrate, unify, and contextualize disparate data streams, internal and external, into a single logical data image via a software platform.
Data Ingestion	Data ingestion is the process of obtaining and importing data for immediate use or storage in a database. To ingest something is to take something in or absorb something. Data can be streamed in real time or ingested in batches. In real-time data ingestion, each data item is imported as the source emits it. When data is ingested in batches, data items are imported in discrete chunks at periodic intervals of time.
Data Lake	A data lake is a storage repository that holds a vast amount of raw data in its native format until it is needed for analytics applications. While a traditional data warehouse stores data in hierarchical dimensions and tables, a data lake uses a flat architecture to store data, primarily in files or object storage. That gives users more flexibility on data management, storage and usage.
Data Pipeline	A data pipeline is a network system that allows data to be moved from a source location to a target location.
Data Visualization Tools	Data visualization tools provide data visualization designers with an easier way to create visual representations of large data sets. When dealing with data sets that include hundreds of thousands or millions of data points, automating the process of creating a visualization, at least in part, makes a designer's job significantly easier. These data visualizations can then be used for a variety of purposes: dashboards, annual reports, sales and marketing materials, investor slide decks, and virtually anywhere else information needs to be interpreted immediately.
Deployment	Deployment services support the implementation and rollout of new applications or infrastructure. Activities may include hardware or software procurement, configuration, tuning, staging, installation and interoperability testing.
Digital twin	A digital twin is a digital representation of a real-world entity or system. The implementation of a digital twin is an encapsulated software object or model that mirrors a unique physical object, process, organization, person or other abstraction.

Term	Description
Incremental learning	In computer science, incremental learning is a method of machine learning in which input data is continuously used to extend the existing model's knowledge i.e. to further train the model. It represents a dynamic technique of supervised learning and unsupervised learning that can be applied when training data becomes available gradually over time or its size is out of system memory limits. Algorithms that can facilitate incremental learning are known as incremental machine learning algorithms.

References

Parent Documents

The parent documents establish the criteria and technical basis for the existence of this document. The parent documents are listed in the following table.

Reference	Code	Title
[PD-1]	DoA	Drones4Safety Description of Action
[PD-2]	ADAGLD	Anomalies description, annotation guide and labelled dataset

Applicable Documents

Applicable documents are those documents - whose content are considered to form a part of this document. The specified parts of the applicable documents carry the same weight as if they were stated within the body of this document. The applicable documents are listed in the following table.

Reference	Code	Title
[AD-1]	ADAGLD	D4S – D4.1 – Anomalies description, annotation guide and labelled dataset– v1.0 – 2021-02-25
[AD-2]	SUADNNM	D4S – D4.2 – Supervised/unsupervised anomaly detection neural network models– v1.0 – 2022-05-30

Reference Documents

Reference documents are those documents that, although not a part of this document, serve to amplify or clarify its contents, or dictate work policy or procedures. The specific reference documents are listed in the following table.

Reference	Code	Title
[RD-1]	AKB	Alteia Knowledge base https://help.alteia.com/
[RD-2]	GGfIT	Gartner glossary for Information technology https://www.gartner.com/en/information-technology/glossary
[RD-3]	AP	Alteia platform https://app.alteia.com/login
[RD-4]	APSDKdoc	Alteia Python SDK documentation https://alteia.readthedocs.io/en/latest/code_examples.html#
[RD-5]	APSDK	Alteia Python SDK code https://github.com/alteia-ai/alteia-python-sdk

2. Introduction

The Drones4Safety (D4S) project aims to increase the safety of the European civil transport system by building a cooperative, autonomous, and continuously operating drone system that will be offered to railway and bridge operators to inspect their transportation infrastructure accurately, frequently, and autonomously.

The Drones4Safety approach will design energy harvesters to tap energy from the overhead electricity infrastructures of railways and power lines to recharge drones.

The project will use satellite and open maps to identify the parts of the transport infrastructure that lays near the electricity infrastructure and feed that information to its drones for scheduling their autonomous missions.

The project will develop and improve the state-of-the-art artificial intelligence algorithms to optimize the inspection results onboard of the drone.

The project will build a swarm drone system that uses advanced low power long range communication network techniques to inspect different parts of the infrastructure at the same time.

Navigation based on advancements in EGNOS/Galileo GNSS will improve accuracy of geo-location of inspection events.

The project's outcomes will be offered to the transportation operators in forms of software services and hardware drone systems. The project brings together leading industrial, research, and academic experts in infrastructure inspection, energy harvesting, artificial intelligence, communications, and drone technology. Two use-cases for bridge and railway inspections will be conducted to evaluate the project outcomes.

This document is part of the deliveries related to the development of artificial intelligence algorithms for defect detection in bridges and railways

2.1. Purpose, scope and content of the document

The purpose of this document is to describe the software platform adopted to display the digital twin of the structures analyzed with the context of the Drones4safety project (i.e., bridges and railways).

Originally the task 4.4 connected to this deliverable aimed at developing from scratch a new software tool able to:

- display 2D data (images with detected defects)
- display 3D data (3D models obtained either with photogrammetry or Lidar) and navigate over the model
- perform measurements in the data shown

The development part of this task 4.4 was finally de-scoped as a consequence of the availability, thanks to Alteia (Delair's spin off created in 2020 in order to offer enterprise solutions of visual intelligence AI based), of a web platform capable of overmatching the original task's requirements.
The Alteia platform, is an easily deployable platform for rapidly integrating, managing and securing visual data and has been proposed as official tool for ingesting and managing Drones4safety visual data.

3. The Alteia platform

The Alteia platform, is an easily deployable platform for rapidly integrating, managing and securing visual data and has been proposed as official tool for ingesting and managing Drones4safety data.

For accessing the platform, please refer to [RD-3]
A free account for viewing data has been created for all project members.

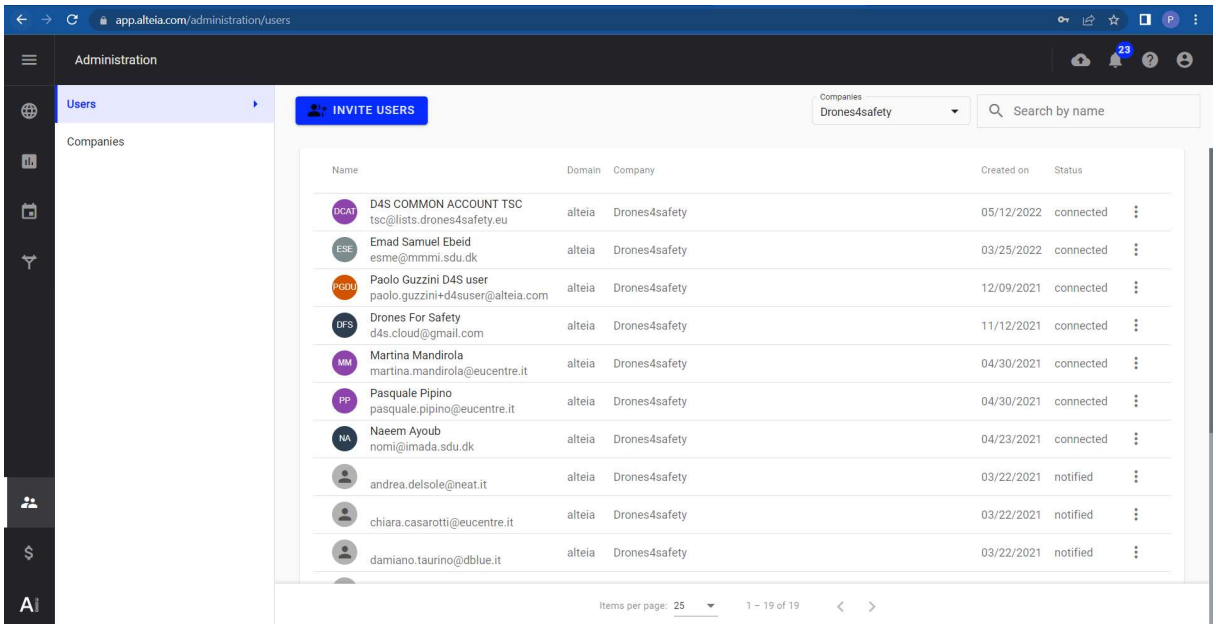


Figure 2: list of users for D4S company [RD-3]

The platform's architecture is based on 3 main pillars

- FUSE: **capability to combine data** in a unique repository and navigate 2D and 3D datasets
- BUILD: **accelerate the development** of AI-based applications than
- DEPLOY: capability of **deploying AI applications** that seamlessly work with existing data storage, enterprise source systems, tools, and underlying infrastructure.

3.1. Fuse

Alteia platform's FUSE capability enables to integrate, unify, and contextualize disparate data streams, internal and external, into a single logical data image.

In particular thanks to the FUSE capability the Alteia platform enables to:

- **Combine data** into a single stream with the contextualization and cataloging tools.
- **Run operations** on visual data with the enterprise transformation models and photogrammetry engines.
- **Navigate and visualize** any data model (in 2D and 3D), and explore complex data dependencies using powerful visualization tools.

There are **9 main pillars** representing the **FUSE capability** of the Alteia platform.

3.1.1. Data pipeline connector

A Data Pipeline connector is featured by:

- Access cloud and on-premise data sources with pre-built connectors. Developers and data engineers can use these connectors to integrate data on the Alteia platform without developing any custom integrations.
- Data ingestion interfaces, data capture module.
- Databases (SQL, no SQL).
- Data streaming pipeline (Kafka).
- File systems including AWS S3, Azure Data Lake Store gen2, local file systems.

3.1.2. Data Visualization

Experience built-in visualization tools for 2D and 3D to automatically generate an internal representation of all data available on the platform to accelerate web visualization.
The Data Visualization tools allow for contextualized navigation by date, location, or type of business attribute.

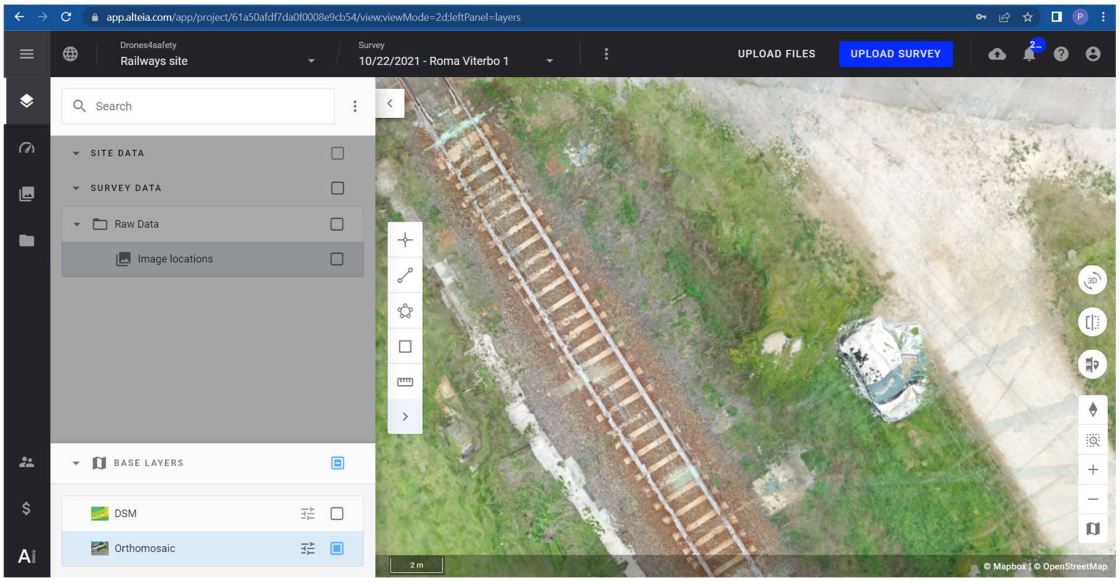


Figure 3: example of Orthophoto visible in the 2D map [RD-3]

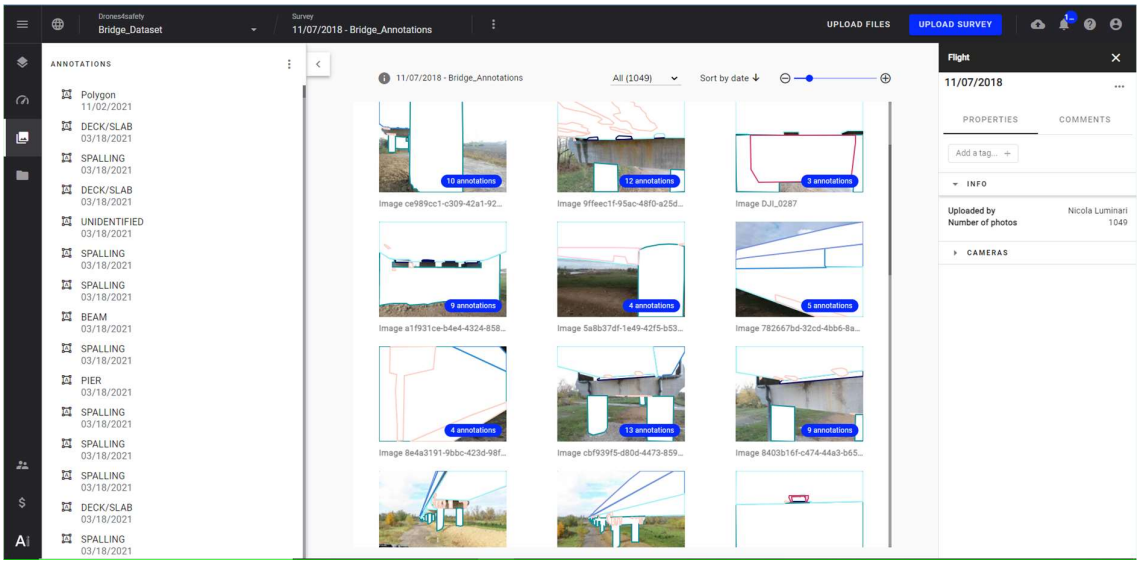


Figure 4: example of annotated pictures available on the gallery [RD-3]

3.1.3. Data contextualization

The Alteia platform provides built-in tools relying on artificial intelligence to **contextualize data** and accelerate data analysis.

Contextualization can reduce the amount of data based on various inputs like applications, services, or users. Its true power lies in improving the scalability and efficiency of data process, query, and delivery.

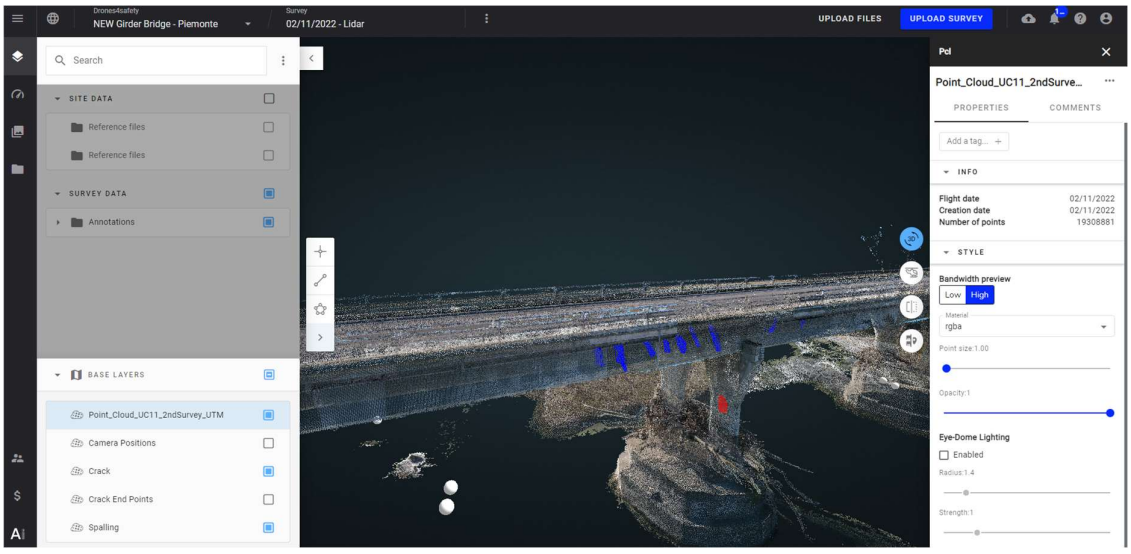


Figure 5: example of data visualization (3D) with data contextualization (defects placed on 3D model with different cameras used to take pictures) [RD-3]

3.1.4. Enterprise data catalog

With the Enterprise Data Catalog, developers and business users can access all relevant metadata on data objects, features, and machine learning models through an enterprise data catalog.
The Enterprise data catalog enables users to:

- Capture technical and business metadata about data and machine learning models via a flexible and powerful cataloging system.
- Discover and trace lineage from source systems to machine learning models for an end-to-end view of your data.
- Easily maintain where the data comes from and who owns it and uses it for data analysis and extended collaboration.
- Accelerate data discovery by applying custom tags to the metadata.

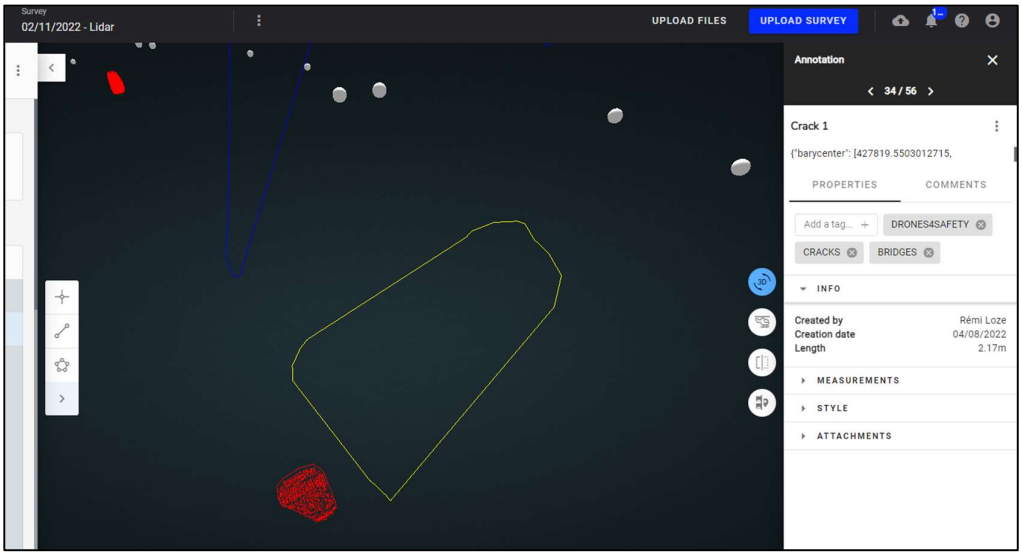


Figure 6: example of business metadata with tags [RD-3]

3.1.5. Unified data model

Alteia's structure is on top of a unified data model. It takes advantage of the elasticity and scalability of cloud-based storage to analyze large volumes of diverse and co-registered data and take advantage of flexible compute resources.
With an abstraction layer between the underlying storage formats, and the application programming interface (data model), unified data can accelerate the development of new machine learning models and insights.
A unified data model can also reduce the redundancies and potential inconsistencies of multiple copies of data in the enterprise.

3.1.6. Data Transformation tools

Data Transformation tools enable users to apply specific rules to a set of data and transform its attributes or features.

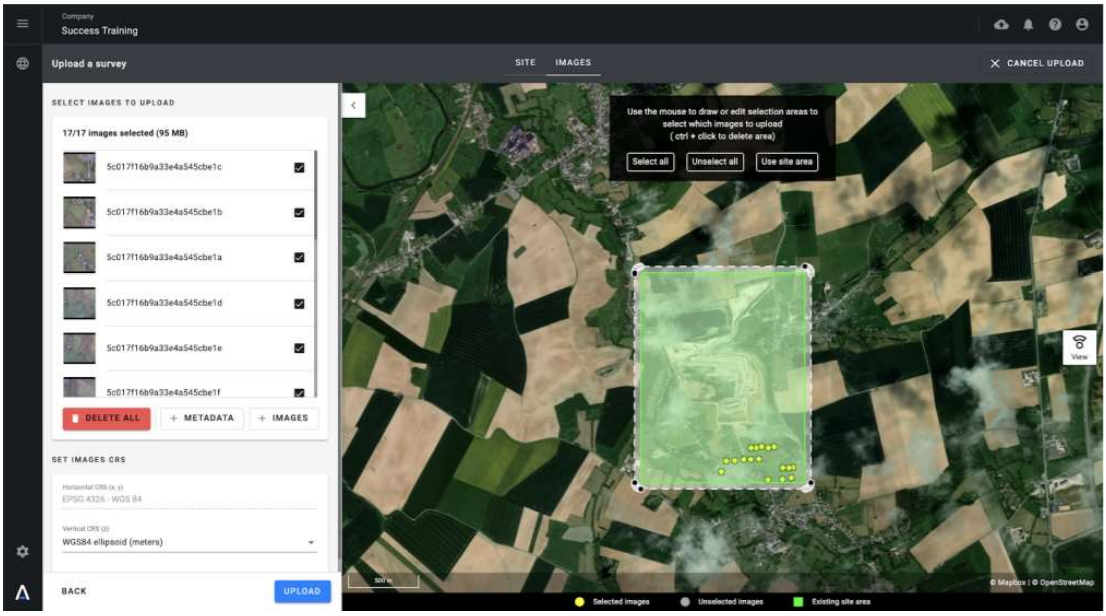


Figure 7: example of metadata associated with a set of uploaded pictures [RD-3]

3.1.7. Mobile Application

Experience effortless data collection in the field or ground truthing with Infield, Alteia's mobile application (available on iOS and Android).

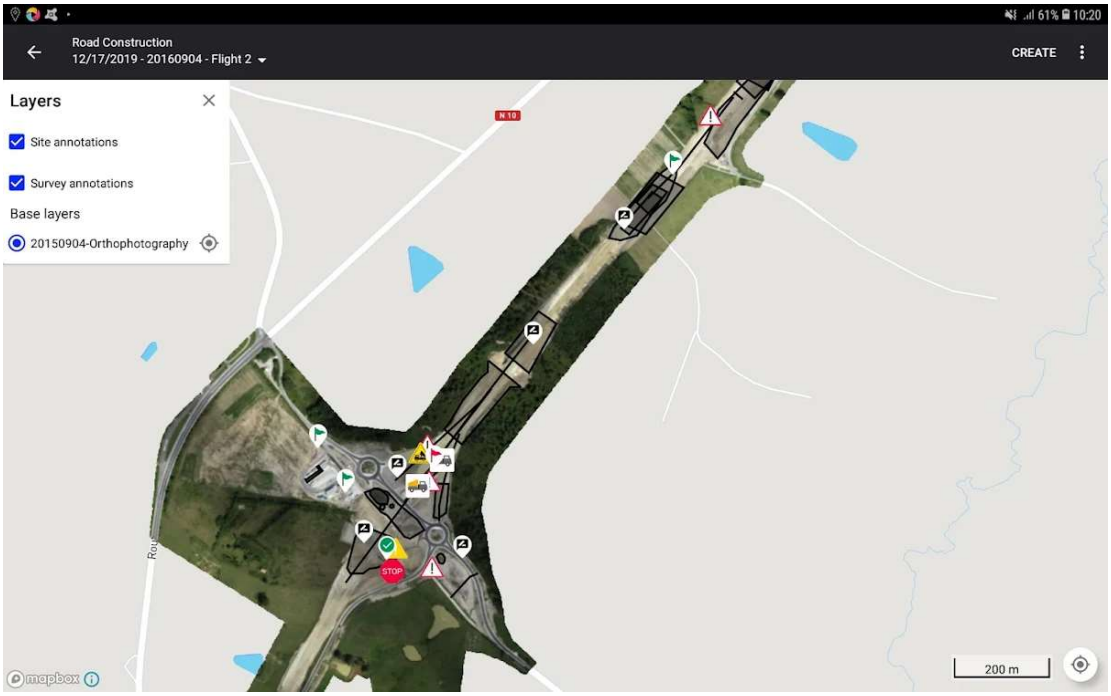


Figure 8: example of Alteia Infield app [RD-3]

3.1.8. Data pipeline manager

The Data Pipeline Manager offers a comprehensive suite of tools to schedule data acquisition campaigns, manage teams, and automatically generate the desired outputs.

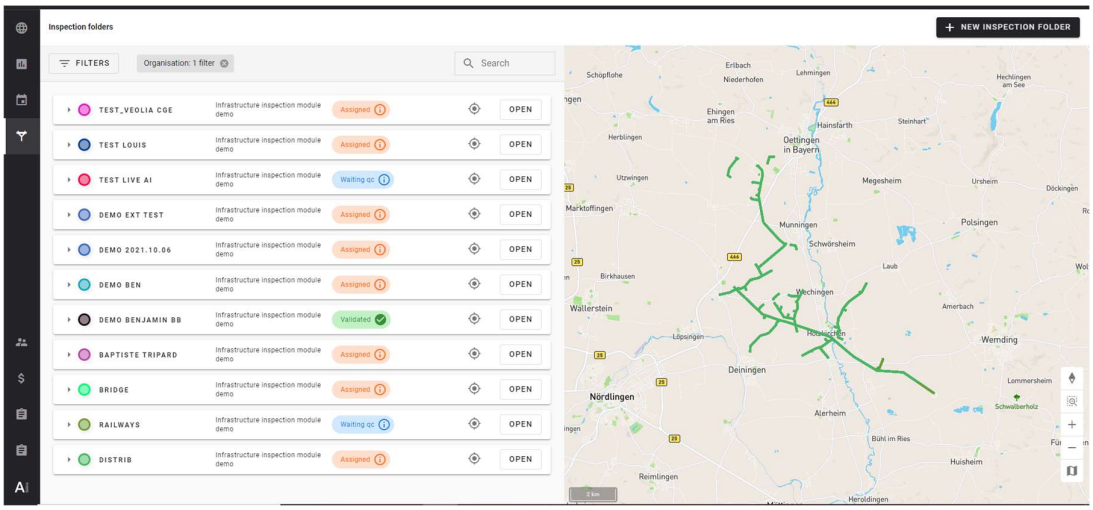


Figure 9: example of dashboard to schedule data acquisition campaigns [RD-3]

3.1.9. 3D & Photogrammetry pipeline

Ingest, transform, and contextualize 3D models and other visual data (Orthmosaics, DSM, DTM, etc.). Visually explore and assess complex data dependencies. Design better models faster.

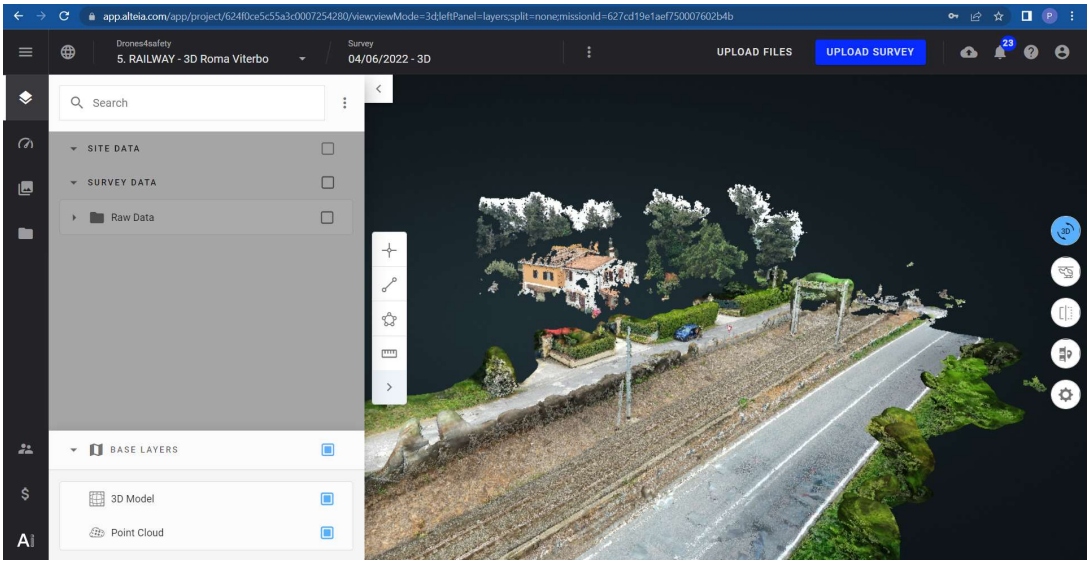


Figure 10: example of 3D model for railway derived from photogrammetry [RD-3]

3.2. Build

The Alteia platform offers a variety of tools to accelerate the development of AI-based applications.

- **Use Time Series** to get the historical information that can be analyzed by AI and ML algorithms to generate and test predictive models.
- **Leverage pre-built ML models** or build upon them to reflect your unique business process. If you want something still more bespoke, you can develop custom object models.
- **Label data with internal and external teams** simultaneously.
- **Implement incremental learning** workflows.
- **Compute and cross-analyze information** using intuitive user interfaces.

3.2.1. Enterprise ML Packages

Make use of a variety of pre-built ML models to accelerate the development of enterprise AI applications. These packages contain methods for predictive analytics such as anomaly or object detection, task segmentation, and point cloud classification. Companies can also choose to extend these pre-built object models to reflect their unique business process or develop custom new object models.

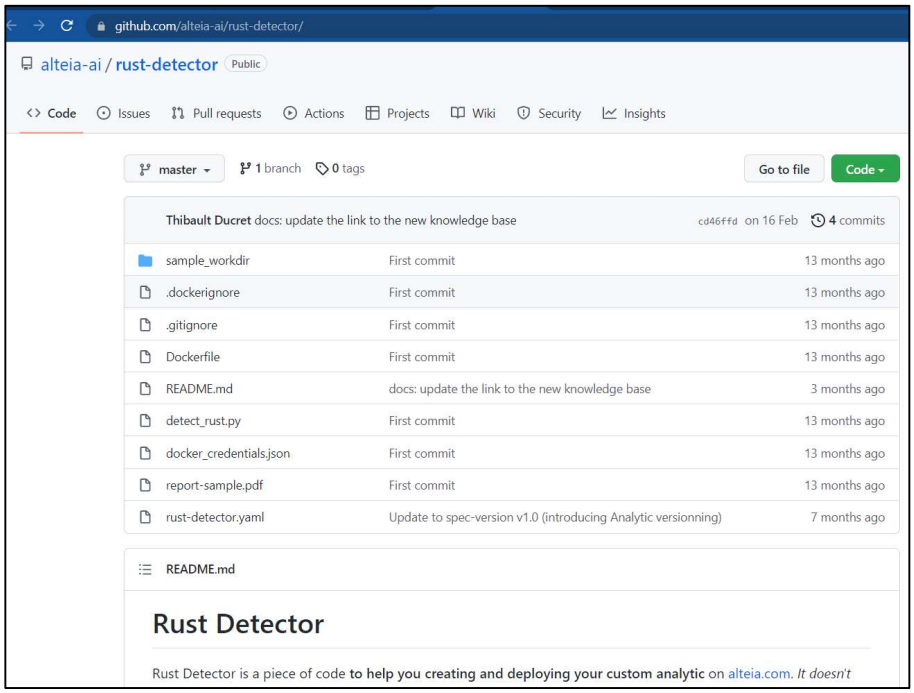


Figure 11: example of code to develop and deploy custom analytics in the platform [RD-5]

3.2.2. Time Series Analytics

The Alteia platform offers a suite of tools that support creating and using **time series data** for AI applications. Time series refers to a list of data points in time order. Time series are essential for representing the change in value over time of data relevant to a particular problem, such as inventory levels, equipment temperature, or wear and tear. Time series data provides the historical information

needed for analysis by AI and ML algorithms to generate and test predictive models. With correct cleansing, normalization, aggregation, and combination, time series data can represent the state of a process over time to identify patterns and correlations to create and evaluate predictions applicable to future behavior.

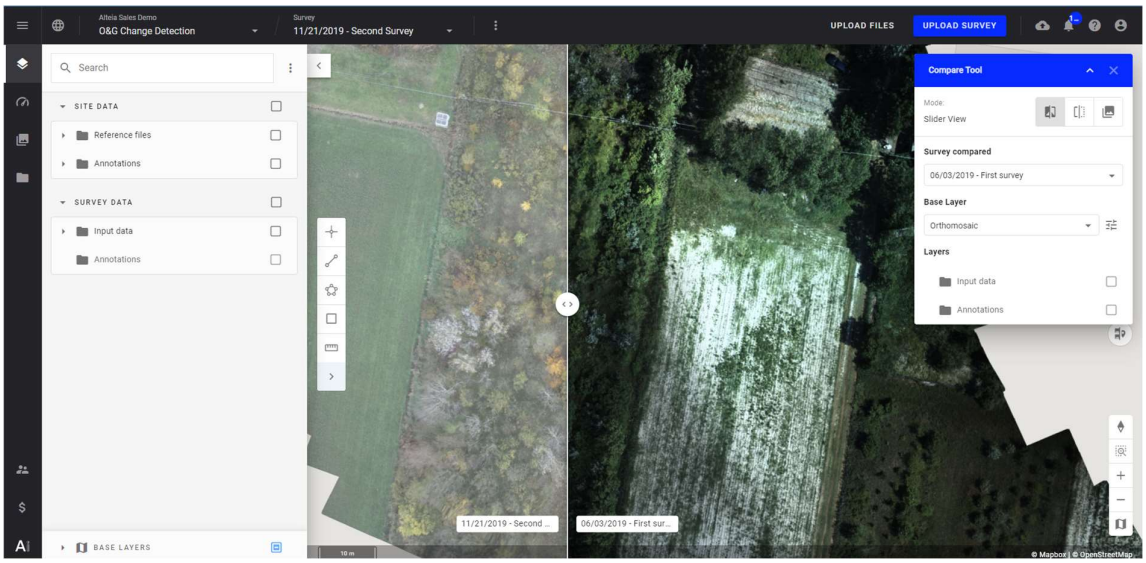


Figure 12: example of analytic based on time series [RD-3]

3.2.3. Smart Annotation Tools

With the Smart Annotation Toolkit, users can simultaneously label data with internal and external teams and work collaboratively to review and comment on annotations. It can be used to implement incremental learning strategies while tracking your activity and progress.

- Bounding box
- Points & lines
- Polygons
- Support for tiled imagery (slippy maps)

Figure 13: example of annotations on pictures via the UI of the Alteia platform [RD-3]

3.2.4. Data Computational Toolkit

Enable a variety of pre-built logic-based algorithms that can accelerate the development of visual intelligence. These tools do not just enable the calculation of distances, surfaces, and volumes but also the analysis of reflectance maps and other types of indexes. You can also choose to extend the pre-built tools to reflect your unique business process or develop custom new packages.

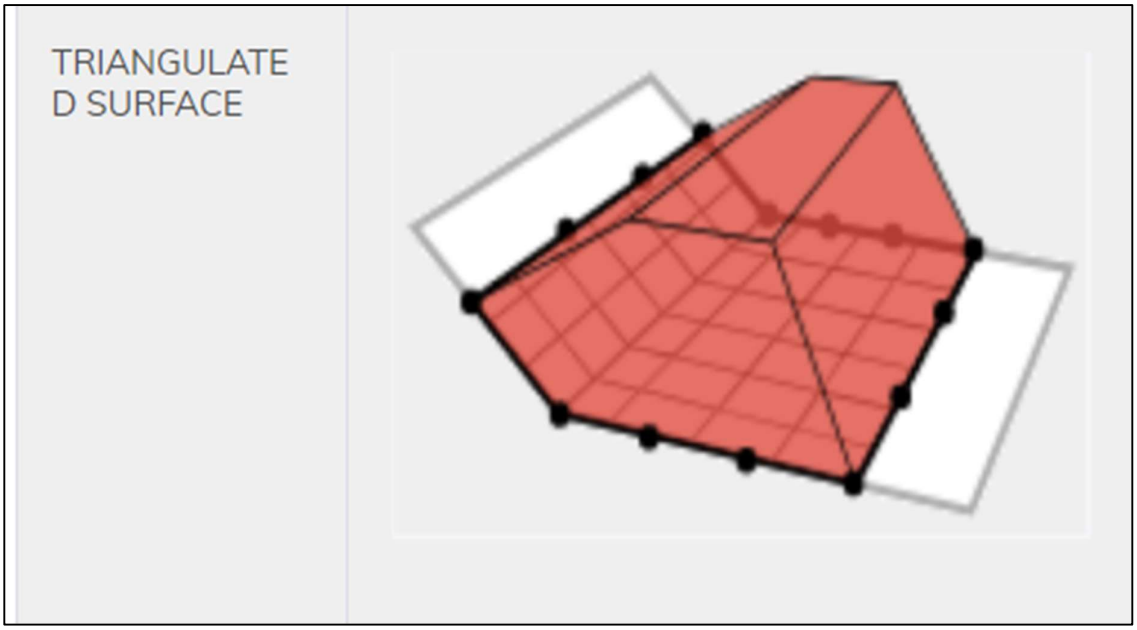


Figure 14: Example: The Triangulated surface option calculates the volume between the surface model and an interpolated base surface based on the elevation of points on the polygon boundary. [RD-1]

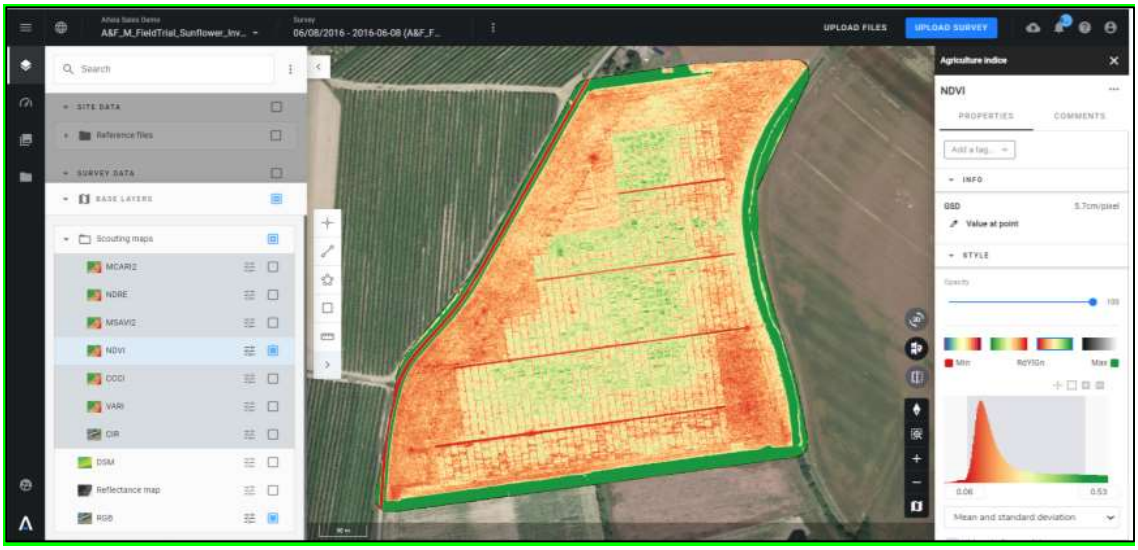


Figure 15: Example of NDVI (Normalized Difference Vegetation Index): Map to analyze vigor, that is mix of biomass development and crop health. The basic tool to scout for field anomalies.[RD-3]

3.3. Deploy

The Alteia platform enables the **deployment of AI applications** that seamlessly work with existing data storage, enterprise source systems, tools, and underlying infrastructure.
It is designed to connect to and work in harmony with major cloud infrastructure and service providers without compromising on data governance, compliance, and security requirements.

- Monitor all aspects of the platform for improved performance.
- Fully control user access and user management.
- Implement feedback loops for quality control and incremental learning.
- Leverage the set of APIs and SDK for easy integration into your existing software environment.

3.3.1. Customer Managed Security

Alteia's security program is based on International Security Standards (ISO 27001) in compliance with the General Data Protection Regulation ("GDPR").

Security is governed by a strict set of policies, procedures, and controls:

- **Data is encrypted** in transit and within the platform on an S3 level through KMS (Key Management Service).
- Security processes are taken into account in a secure **software development lifecycle**.
- **Granular role-based access** controls allow users to adjust their team members' access to data, toolsets, and editing privileges.
- Audit tools provide a detailed record of actions of every user within the Platform and the Alteia application.
- Experience secure and reliable systems with virtual private clouds / networks that are accessible over robust network infrastructure.

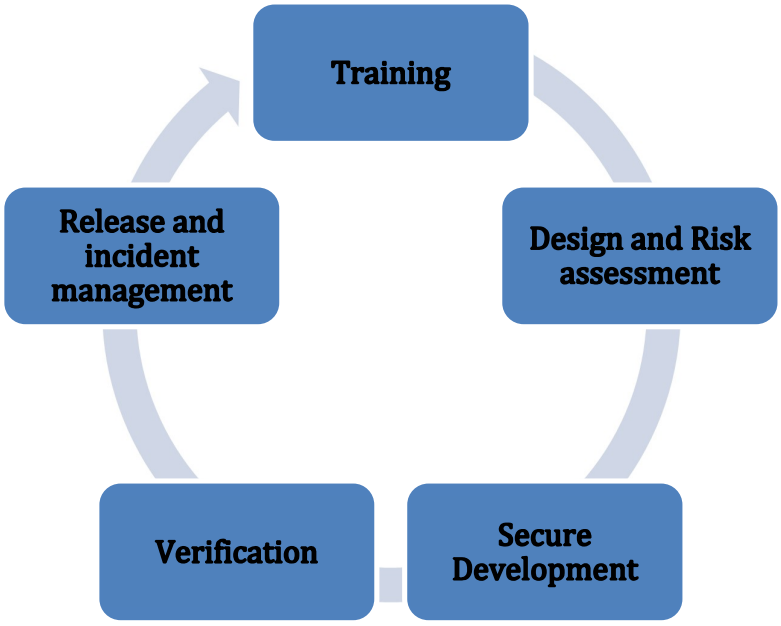


Figure 16: example of security software life cycle [RD-1]

3.3.2. Single Sign-On

- Select any SAML v2.0 compliant identity provider.
- Leverage two-factor authentication support to meet advanced authentication requirements.
- Delegate user authentication and authorize third-party applications to access the Alteia AI platform.

3.3.3. Feedback Loop

Alteia provides feedback loop workflows for incremental learning. A feedback loop, or closed-loop learning, describes the process of leveraging the output of an AI system and corresponding end-user actions to retrain and improve models over time.

The AI-generated outputs (predictions or recommendations) are compared against the final decision (for example, to perform work or not) and provide feedback to the model, allowing it to learn from its mistakes.

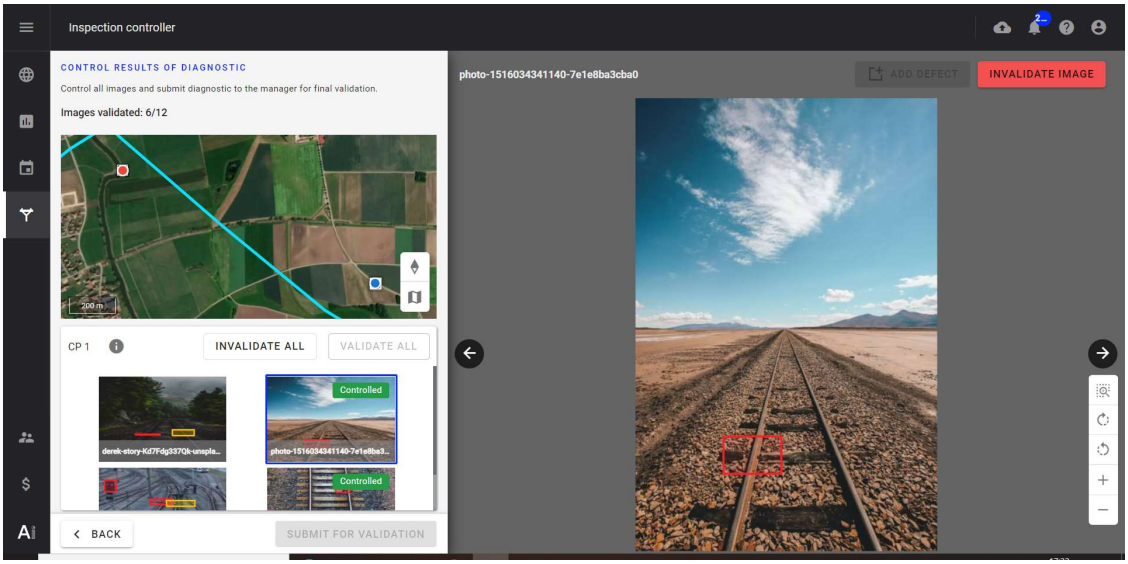


Figure 17: example of validation process of AI results for future incremental learning [RD-3]

3.3.4. User Management

- Leverage the Alteia platform's comprehensive approach for managing access to data, APIs, and infrastructure resources.
- Segregate duties within the team and limit user access to resources or create implications in the business process based on job requirements.
- Define expressions selectively to provide or restrict access to application and infrastructure resources.
- Share information, organize your change management, and define your organizational processes.

Alteia User Roles Table	Manager	User	Contributor	Operator
Actions Allowed				
Create a Site	✓	x	x	x
Upload a Survey	✓	x	x	x
Invite new users	✓	x	x	x

Figure 18: example of user role matrix [RD-1]

3.3.5. APIs

The Alteia platform is offered with a Python Software Development Kit (SDK) with **APIs.** It is an additional **set of software standardized tools that allows to develop data exchange** and processing with Alteia.

In particular thanks to API, it is possible to manage:

- The data ingestion.
- The data analysis launching analytics.
- The data management: it is possible to organize data and set terms for how your users interact with it with the Project Management API. Further organize per location (projects) and acquisition date (mission).
- Access to thousands of low-level micro-services with thousands of documented endpoints.
    - Map service
    - Feature Service
- Map Service
- Annotation API

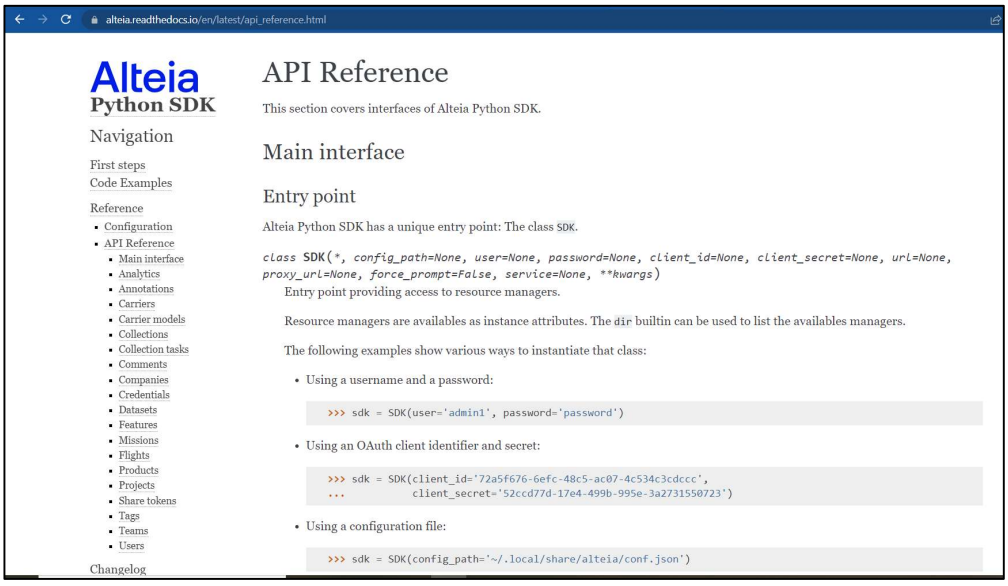


Figure 19: API reference main page for Alteia platform [RD-4]

3.3.6. SDK

The Alteia **Software Development Kit** (SDK) is an additional set of standardized software tools that allows you to develop data exchange and processing directly with Alteia.

Used to create, test, and develop specific applications quickly, on top of the current Alteia platform, and then industrialize them to integrate the Alteia platform with other applications seamlessly.

It enriches the platform with advanced functionalities, industry-specific or customer-specific analytics, push notifications / data, and more.

Everything needed to create your own modules and analytics is included, such as a code library, examples, documentation, and the methodology necessary to perform specific functions.

Figure 20: print screen of the Python SDK page [RD-4]

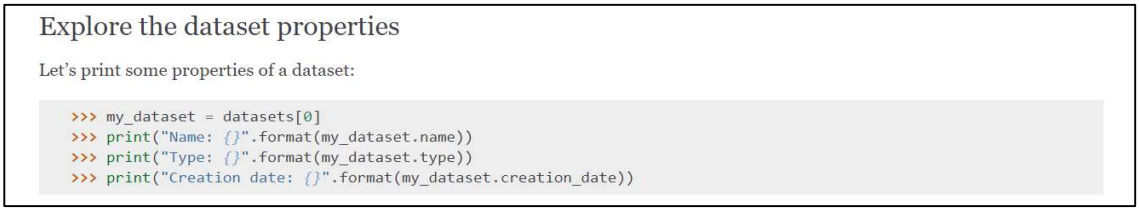


Figure 21: example of available code [RD-4]

3.3.7. Monitoring Console

The Alteia platform includes some advanced monitoring features able to:

- Monitor all aspects of the Alteia platform, from the state of an analytical job to API performance.
- Visualize current and historical environment workload using an intuitive environment operations portal.
- Monitor the status and throughput of invalidation queues, the mechanism by which the Alteia platform handles asynchronous processing requests.
- Configure auto-scaling rules to maintain the cost and availability of compute resources.

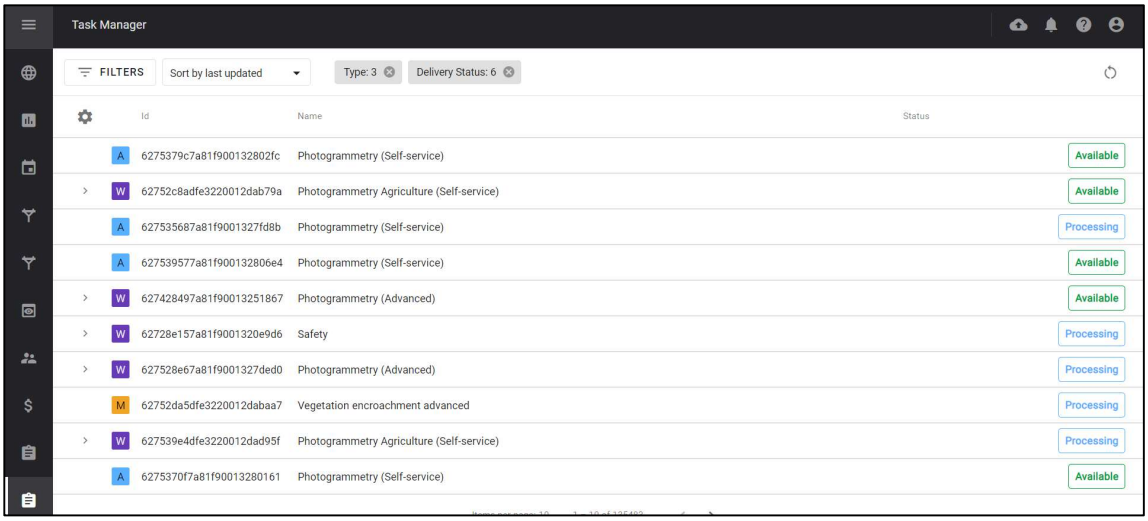
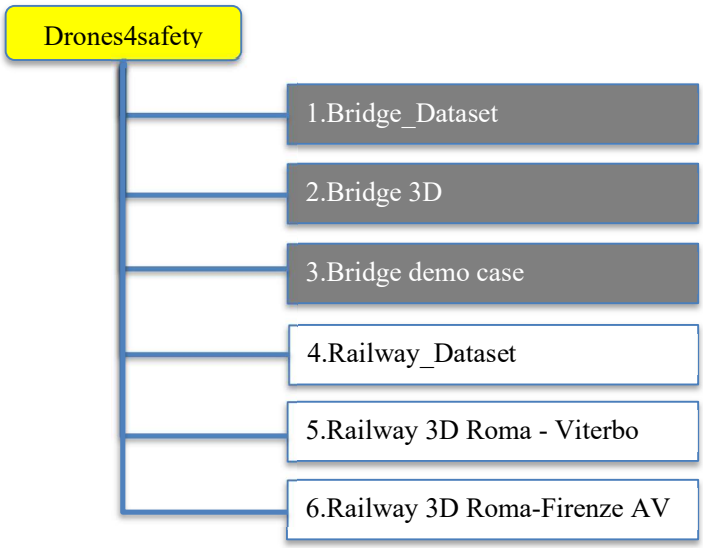


Figure 22: monitoring console for analytics and workflows [RD-1]

4. Drone4safety data into the Alteia platform

A specific data repository for the project has been created inside the Alteia Platform: it is named **Drones4safety.**

The data structure inside the Alteia Platform is according the following architecture



In addition to the 6 official projects there are additional projects created by other project members.

4.1. Bridge section

There are 3 official projects dedicated to bridges

- 1.Bridge_Dataset
- 2.Bridge 3D
- 3.Bridge – demo case

4.1.1. 1.Bridge_Dataset

This project contains all the 1049 pictures (selected from the dataset provided by EUCENTRE) with the related annotations.

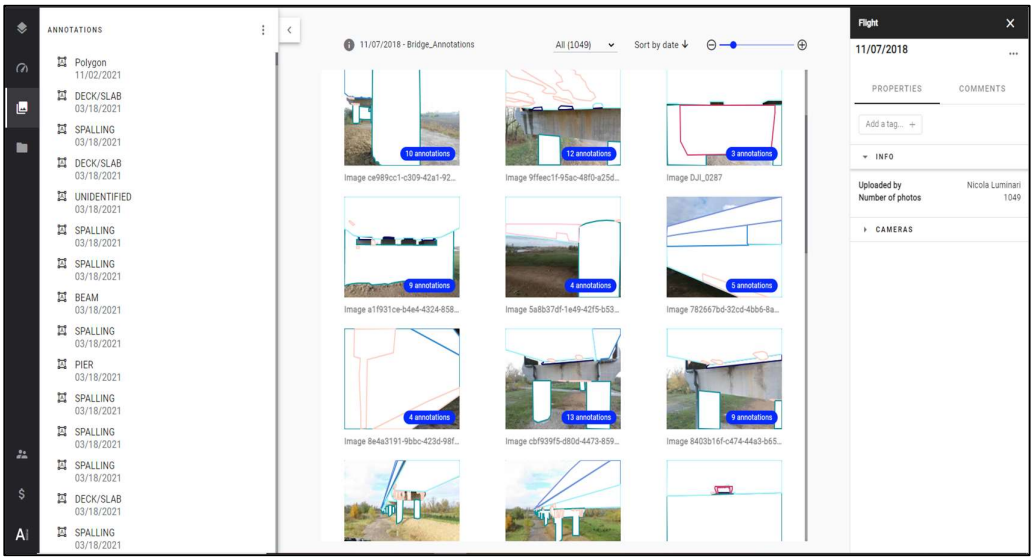


Figure 23: annotated dataset inside the Alteia platform [RD-3]

4.1.2. 2. Bridge 3D

This project contains an example of 3D model of a bridge.
The file LAS containing the 3D model was provided by EUCENTRE.

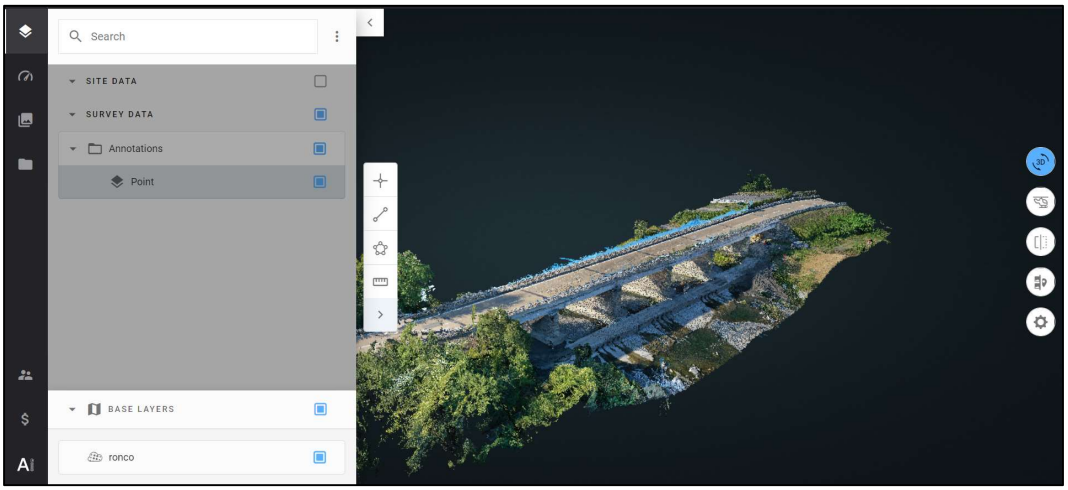


Figure 24: example of a 3D view of a bridge imported in Alteia platform [RD-3]

4.1.3. 3.Bridge demo case

This project contains the 3D model of a bridge in Italy that has been selected as one of the possible bridge Use Case (UC) of WP7 (in particular Task 7.3) for the demo/test of some of the D4S functionalities developed within the project. In particular, for what concerns WP4 the idea, which is currently under investigation within Task7.3, is to simulate the application of the following workflow:

1. Survey and dataset acquisition (in particular RGB pictures) with multirotor drones
2. Digital Twin creation thanks to Photogrammetry
3. AI based defect detection with creation of annotations including position of the image of the identified defect on the 3D model ("3D virtual tour").
4. Simplified procedure for performing bridge structural assessment starting from input information on visible damages and structural data. The idea is to get as much input information as possible from the Alteia anomaly detection and virtual inspection module.

The file LAS containing the 3D model was provided by EUCENTRE. Within the WP7 framework, a collaboration with EUCENTRE is ongoing in order to tune the above-mentioned workflow and, in particular, to test and optimize the virtual tour of this bridge in support to simplified structural analyses.

Figure 25: 3D model of a bridge demo case. The model also shows the camera position (in 3D with the orientation) for the acquisition of the picture containing the identified defect (also shown in the info panel)[RD-3]

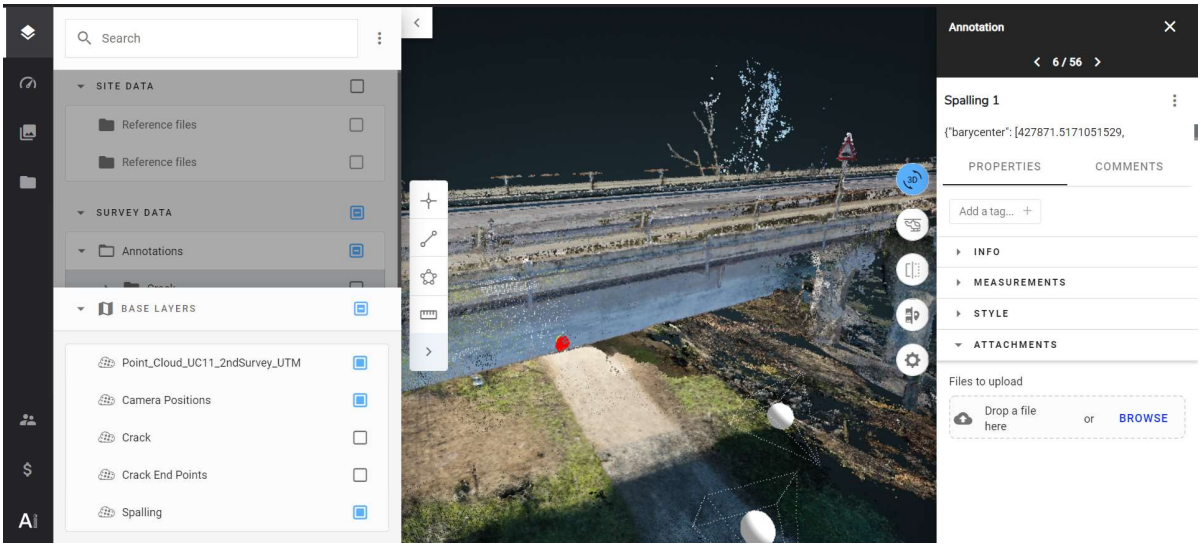


Figure 26: 3D model with the defect area shown in red (for spalling class) and with border including defect relevant info (coordinate of the center of gravity plus surface affected) [RD-3]

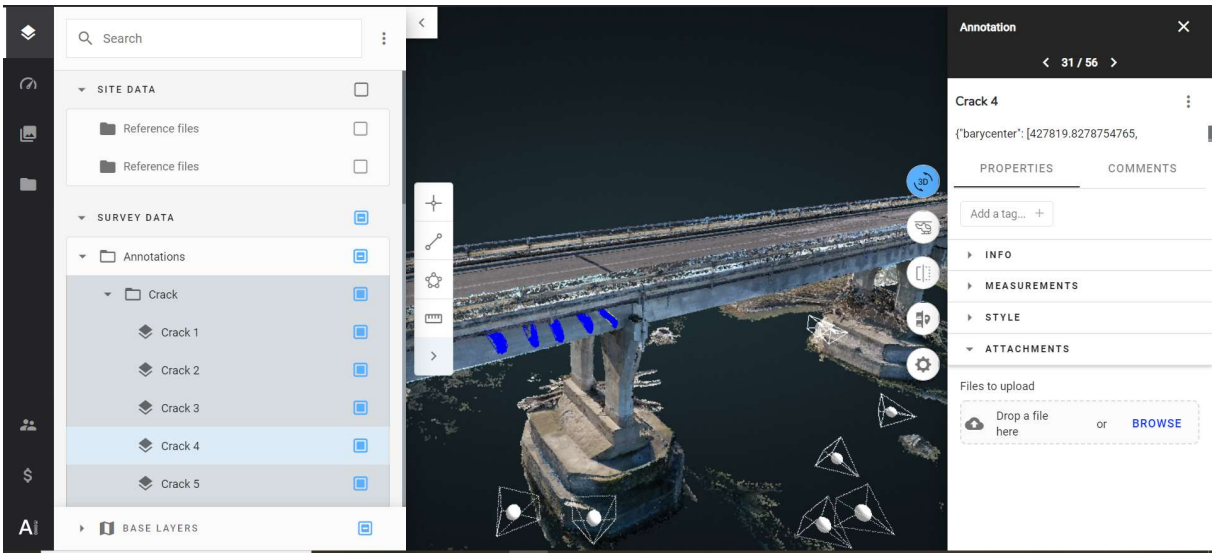


Figure 27: 3D model with the defect area shown in blue (for cracks class) and with border including defect relevant info (coordinate of the center of gravity plus starting and ending point) [RD-3]

4.2. Railways section

There are 3 official projects dedicated to Railways:

- 4. Railway Dataset
- 5. Railway – 3D Roma Viterbo
- 6. Railway – 3D Roma Firenze AV

4.2.1. 4.Railway_Dataset

The railway dataset contains the first 4 surveys carried out by NEAT in different sites in Italy. The 4 surveys are all accessible in the platform and are:

- Survey 1: 281 images of the ground part of the railway Roma Viterbo
- Survey 2: 510 images of the overhead part (mainly) of the railway Roma Viterbo
- Survey 3: 366 images of a railway in the area of Capranica
- Survey 4: 40 images of a railway inside Rome in the district of Vigna Clara

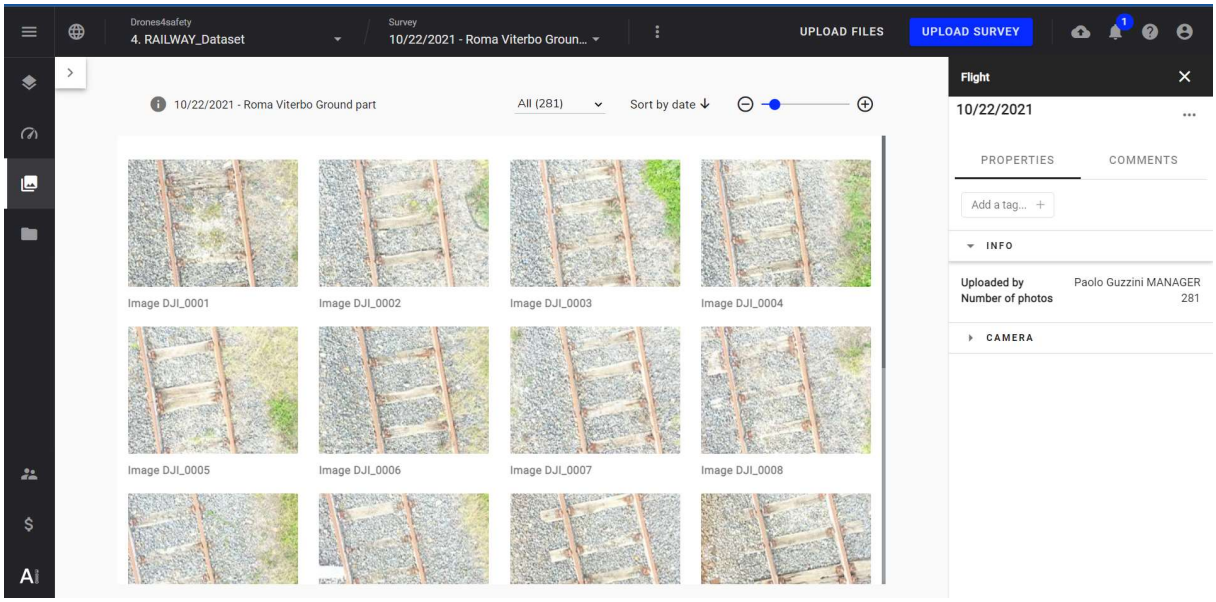


Figure 28: 510 images acquired for the ground part of the line Roma Viterbo [RD-3]

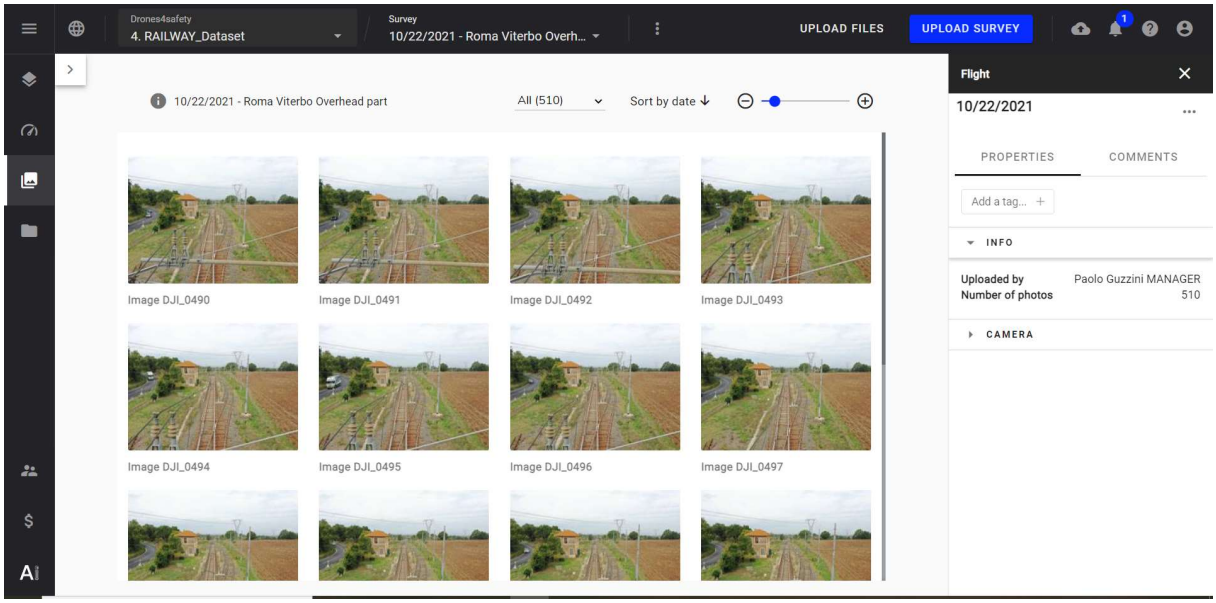


Figure 29: 281 images for the aerial part of the line Roma Viterbo [RD-3]

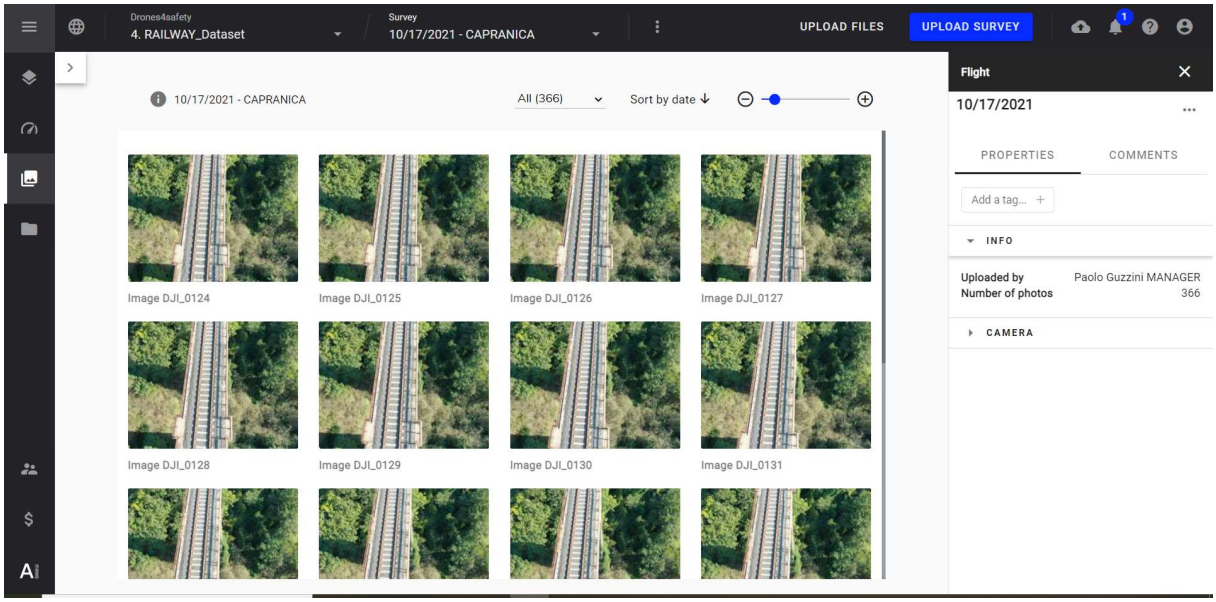


Figure 30: 366 images for the line Capranica [RD-3]

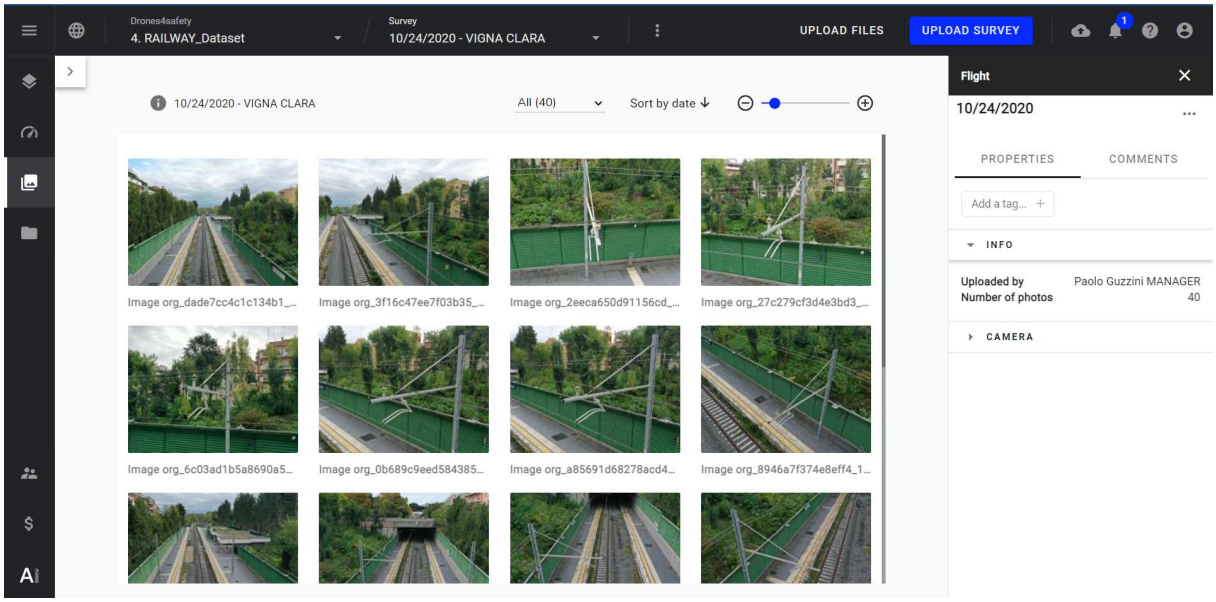


Figure 31: 40 images for Vigna Clara

4.2.2. 5.Railway – 3D Roma Viterbo

The project contains a selection (including 68 images) of the overhead Roma Viterbo dataset mentioned at paragraph 4.2.1 made with the purpose of creating a 3D model.

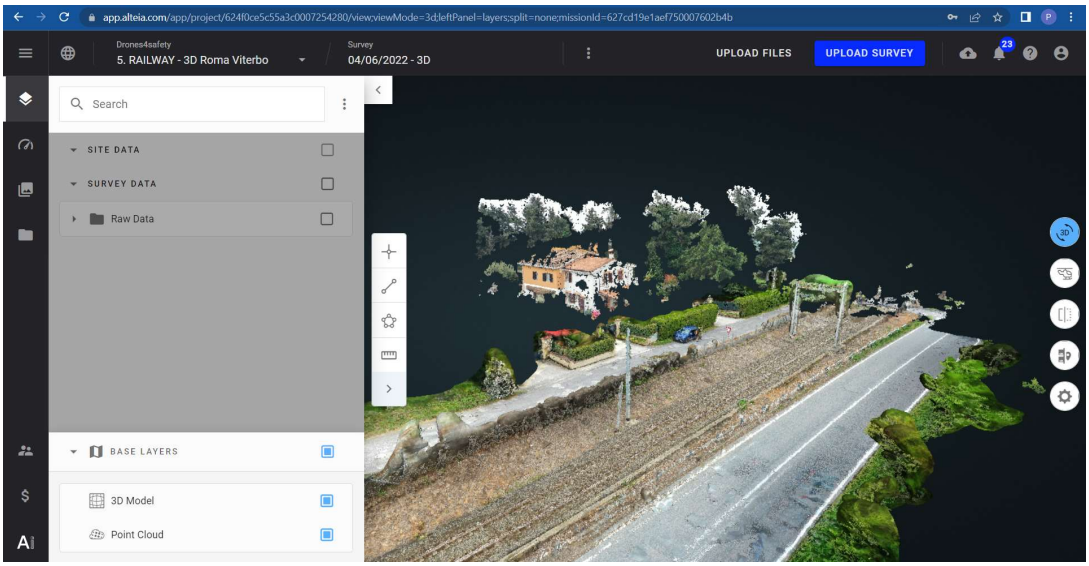


Figure 32: 3D model of a selection of the dataset Roma Viterbo

4.2.3. 6.Railway – 3D Roma Firenze AV

The project contains 582 images acquired over a high-speed railway between Rome and Florence in the area of Rome.

Pictures have been used both for training the AI based algorithm for defect detection and also for producing a 3D model.

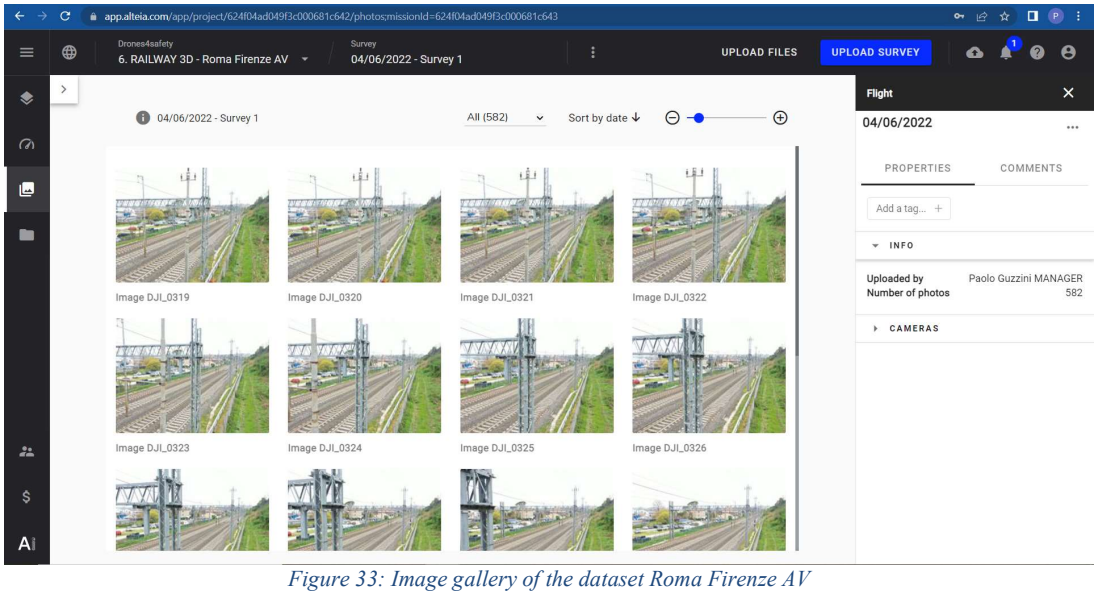


Figure 33: Image gallery of the dataset Roma Firenze AV

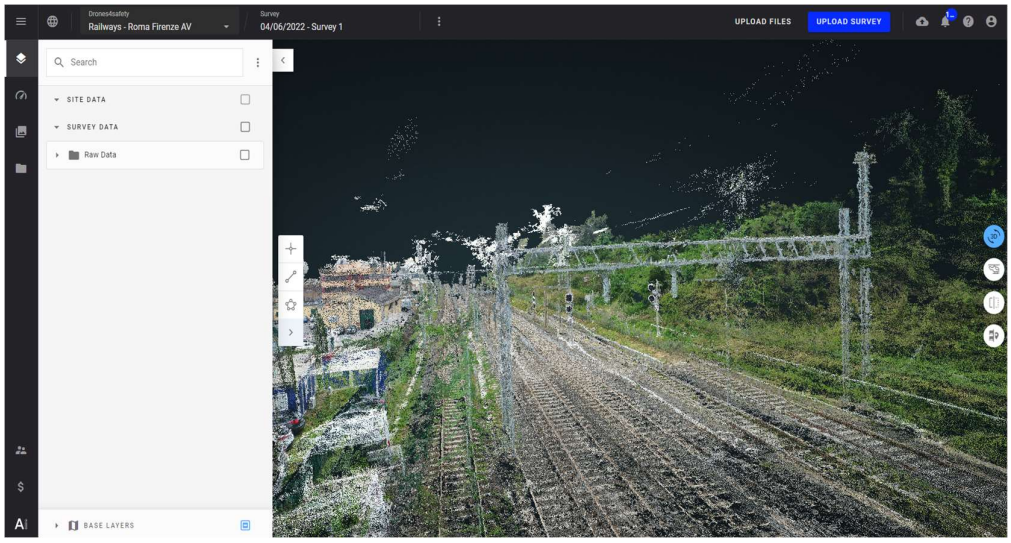


Figure 34: 3D model of the line Roma Firenze AV

5. Conclusions

The Alteia platform, adopted for managing Drones4safety dataset, is, not only 2D and 3D viewing tool (as originally planned in the task 4.4) but a comprehensive platform for rapidly developing, deploying and operating AI applications with visual intelligence.