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DELIVERABLE

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Executive Summary

The purpose of the deliverable is to present and discuss the application developed by Breda University of Applied Sciences (BUas) as one of the Iliad Geo-data and Visualisation modules, which design was described in D6.6 and that will offer end-users the opportunity to visualise marine and maritime geo data in 2D and 3D, both statically and dynamically. The dynamic aspect effectively means introducing a time dimension, which is why this report henceforth refers to the visualisation functionality as "2D, 3D and 4D". This deliverable is one of the direct results of task 6.4 Geo-Data Visualisation – Design and Development, led by Breda University of Applied Sciences.

This deliverable specifically presents the developed application capable of visualising in 2D/3D/4D the diffusion and propagation of microparticles in water. The original design was based on the needs of the potential target audiences for the "Water Quality" pilot, involving in particular Iliad partners Fraunhofer and SINTEF Ocean, and on the data provided by their buoys. This report offers the general overview of the main functionalities of the application that has been developed in the last months.

While the initial design was tightly connected to the previously mentioned pilot, the final idea was to allow anyone to visualise their data through the delivered application, and it is indeed possible to do so, as long as the data respects a predetermined structure or as the parser is modified by the user to their specific needs.

This report also explains and elaborates on possible uses of the application and future developments that might extend its capabilities and versatility.

Deliverable Leader:	Breda University of Applied Sciences
Contributors:	Jacopo Fabrini, Harald Warmelink
Reviewers:	UAB, BLIT, INTRA
Approved by:	Charalampos Ipektsidis (INTRA)

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1.0	23/07/2024	INTRA	QA and creation of the final submitted version

Table of Contents

Table of Figures

Definitions, Acronyms and Abbreviations

Acronym/ Abbreviation	Title
BUas	Breda University of Applied Sciences
UI	User Interface
UX	User Experience
WP	Work Package
WPL	Work Package Leader

1 Introduction

1.1 Deliverable Overview

This report is one of the deliverables for Task 6.4 "Geo-Data Visualisation - Design and Development".

This WP6 task concerns the design and development of a Geo-data and Visualisation module, i.e., new software that will offer end-users the opportunity to visualise marine and maritime geo data in 2D and 3D, both statically and dynamically. The dynamic aspect effectively means introducing a time dimension, which is why this report henceforth refers to the visualisation functionality as '2D, 3D and 4D'.

In the design phase of development, as explained in D6.6, BUas made two decisions. First, to "latch on" to a specific pilot, at least initially. Second, to simultaneously adopt a data-driven approach, i.e., ensure the new software always obtains the source geo data externally rather than "hard-coding" or "baking" it into the software. Combined, these two decisions allowed us to focus our design efforts while ensuring that the resulting software is generic. The software will be able to cover a myriad of geo data and use cases as long as the delivery of said geo data conforms to certain standards.

The specific Iliad pilot that became the focus of the design work was the Water Quality - Plastic Pollution involving, in particular, Iliad partners Fraunhofer and SINTEF Ocean. This pilot is interesting and relevant because it seeks to employ geo data directly from sensors, from aggregations of (remote) sensor data, and from models/simulations. Moreover, it has a clear interest in 2D, 3D and 4D data representations. Finally, the direct sensor data is already being actively gathered and thus immediately available, as multiple advanced sensor prototypes in the form of buoys have already been deployed. The pilot is focused first and foremost on observing and identifying microparticles.

This pilot concerns monitoring the quality of water through Machine Learning analysis of 2D visual data coming from a camera system installed at 10 meters of depth. Machine Learning permits the categorisation of the different microparticles in categories, with a particular focus on:

- Oil Drops, to monitor eventual oil spills.
- Gas Bubbles.
- Microorganisms, that might be dangerous for local aquacultures.
- Marine Mucilage.

The network of sensors in the same sea basin is being extended. It currently counts two buoys containing different kinds of sensors and a camera system, one of which is at the entrance of the basin. New sensors are also being deployed on the sea floor of the basin.

The data provided by this pilot allowed us to create an application capable of parsing a file format (NetCDF) that is widely used within the scientific community treating Geo-Data, but that is also limited to specific scientific applications that provide simple non-interactable visualisations. The developed application, that was codenamed "GeoViz", allows the users to visualise and interact with the data dynamically at runtime, while their simulation is happening.

1.2 Document Scope

The main scope of this document is to detail the outcomes of the development process concerning Task 6.4 "Geo-Data Visualisation - Design and Development" of Work Package 6 "Geo-Data Visualisation".

The development process was entirely based on the design defined in D6.6, but had to steer from it at times, to adapt to the hurdles in development that were not foreseen in the design phase, respecting the cyclic aspect of the AGILE methodology used.

This document describes the main features of the "GeoViz" application, providing multiple screenshots.

The application itself is available in the Iliad Marketplace:

https://ocean-twin.eu/marketplace/product/geoviz

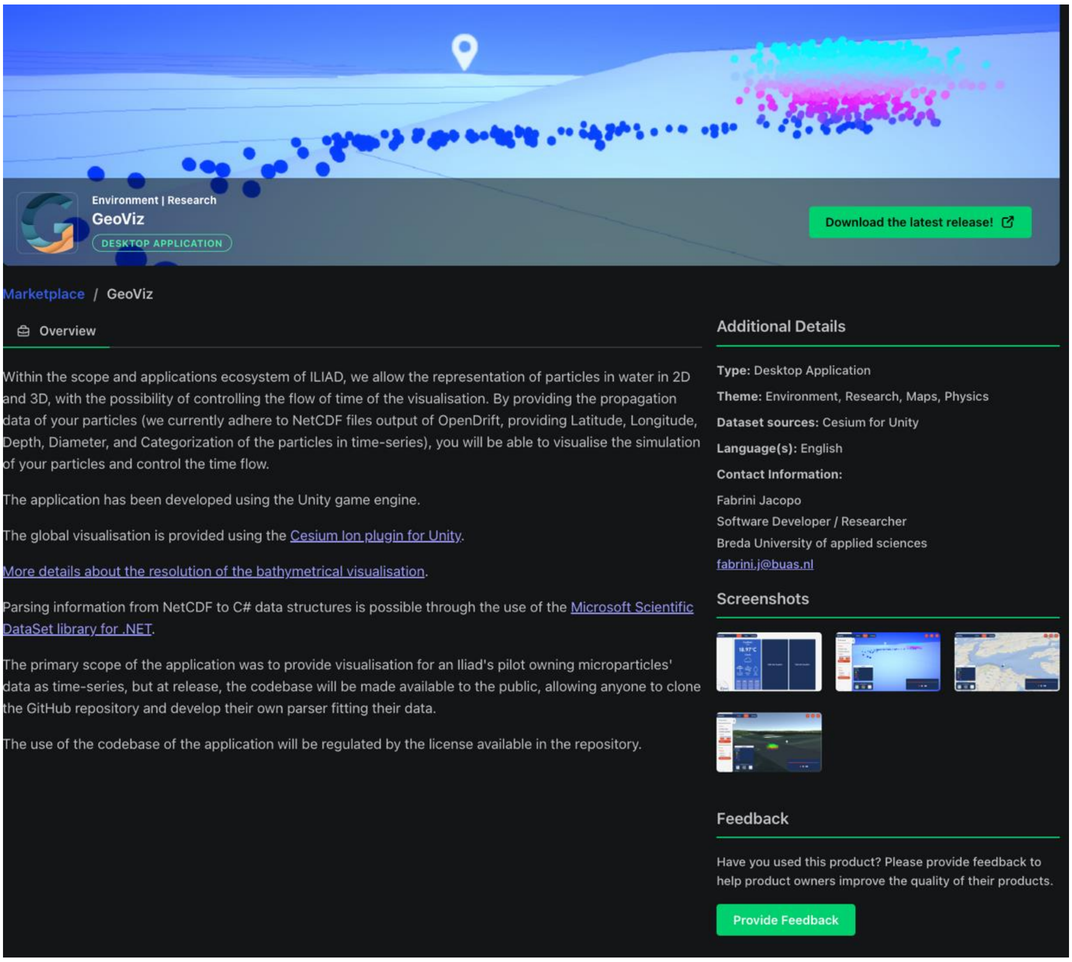

Figure 1: GeoViz page in the Iliad Marketplace

Finally, we present the possibility of future developments, extensions of the application and the aperture to collaborations, granted by the Open-Source license that is being used for it.

1.3 Document Structure

The deliverable is organised in the following sections:

Section 1 introduces Task 6.4 and the structure of the entire document.

Section 2 presents the features of the "GeoViz" application and its screenshots.

Section 3 concludes the document by presenting the opportunities of extensions and adaptations of the application to the needs of different users.

2 Development of the application

2.1 Data Processing

The first challenge dealt with in the development of the application has been the intake, parsing and processing of the data.

In fact, NetCDF is a data format that is not natively processed by the programming language used by Unity3D, that had to be parsed in common C# data structures, and processed to be visualised at runtime, while maintaining a high-level of performance to provide the best User Experience.

2.1.1 NetCDF format

NetCDF (Network Common Data Form) is a community standard for sharing scientific data. It can store multidimensional data such as temperature, humidity, pressure, wind speed, and direction, and each of these variables can be displayed through a dimension, such as time. Its data can be easily visualised using common scientific software such as MATLAB or OpenDrift, but it is not so easily processed by other tools, since it is mostly used by the scientific community to share geo-data. By providing an interactable and user-friendly representation of these scientific data, we wanted to expand the target audience that could interact with this scientific format and improve the visualisation experience compared to that provided by the aforementioned scientific tools.

2.1.2 Microsoft Scientific DataSet Library

The parsing of the data contained in the NetCDF file provided by SINTEF was possible by integrating in the code solution of GeoViz the Microsoft Scientific DataSet (SDS) library. SDS is a managed library for reading, writing, and sharing array-oriented scientific data, such as time series, matrices, satellite or medical imagery, and multidimensional grids. Using it in the project, it was finally possible to extract the data from the NetCDF file and put them in data structures native to C# that could be fed to the simulation system.

2.1.3 Data Variables

To be able to visualise the data spatially, in the world, in 3D and over time (4D), it was needed to have access to the following information from the NetCDF file:

- Latitude
- Longitude
- Depth

These three variables, already displayed as time series, were sufficient to create a simulation showing the position of the particles in the world in terms of time.

Having access to additional information coming from the elaboration of the data done by SINTEF through their sensors, it was decided to improve the intractability of the simulation by providing visualisation of the particles of the following information:

- Particle type

- Particle diameter

The coming chapters will describe specific information on the kind of visualisation and interaction provided with these data.

2.2 Application Overview

In the following chapters the GeoViz application will be described in detail, in its features, and in its aspect using screenshot of its current version. The application will go through an additional stage of polishing and the aspect of the first release might slightly change from what will be displayed here.

2.2.1 Main Page

The homepage is the first page of the application that the user will have access to.

It displays weather information in form of widgets, showing the current temperature, weather, precipitations, wind speed and humidity. It also provides the forecast of the weather and temperature for the upcoming twelve hours.

The page contains one static widget and two widget slots (see Figure 1).

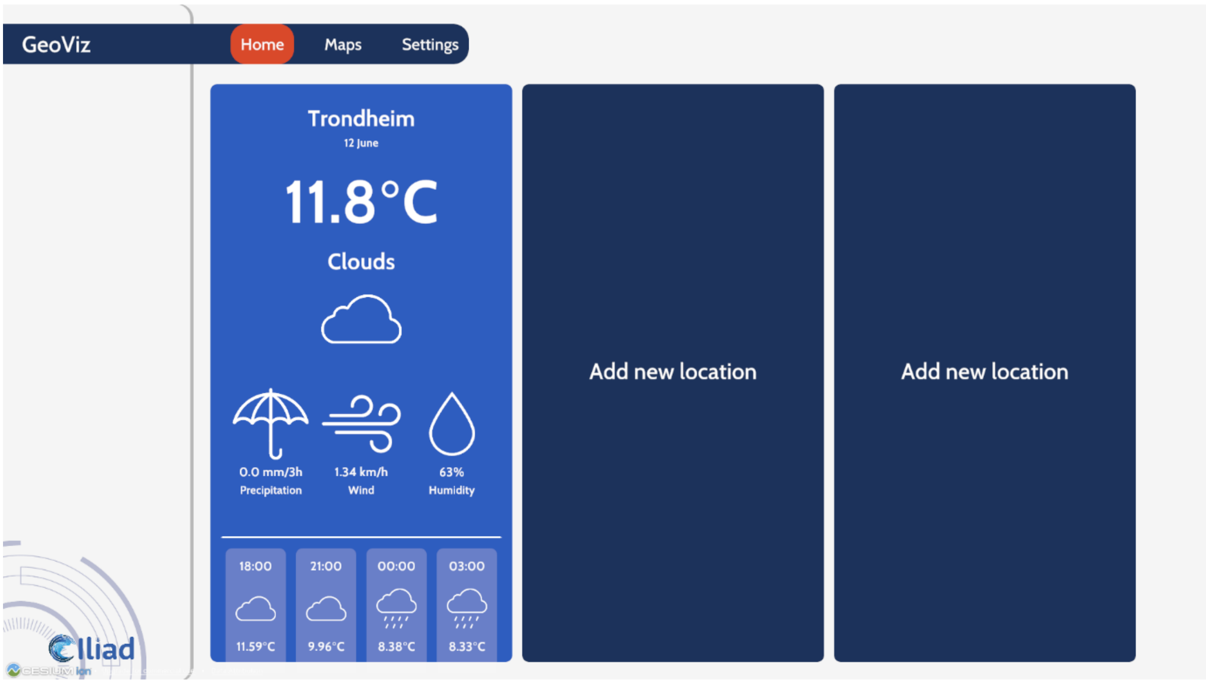

Figure 2: Landing page with weather conditions and customisable widgets.

The static widget cannot be removed and will be automatically filled with the weather information of the place on Earth where the particles that are being simulated are located. The other two widgets can be manually set by the user by clicking on them and providing the latitude and longitude of a location in the pop-out window that will consequently appear (see Figure 2).

Figure 3: Pop-out window to set up a new weather widget on the homepage.

The weather information is provided at runtime by calling the OpenWeatherMap API and is updated each time the user lands again on the homepage.

2.2.2 Maps Page

This page of the application contains numerous core features; for this reason, this chapter will be divided into sub-chapters to provide a detailed description of each.

2.2.2.1 Map Visualisation (Cesium)

While SINTEF provided all the information concerning the particles, the data concerning the visualisation of the area where the particles were located was still missing.

In the scope of developing an application as generic as possible that could be used with data coming from anywhere in the world, it was decided not to limit the data visualisation to the Gulf of Trondheim.

For this reason, it was decided to use the Cesium plugin for Unity. Cesium is a complete platform for 3D geospatial data. Specifically, we used Cesium ion, as this service provides curated 3D global content, and includes multiple visualisations of the Earth, and its bathymetry (with different resolutions).

2.2.2.2 Map Selection

Three different types of Earth visualisations are provided to the user and can be chosen from the dedicated map selection window.

The three visualisations are:

- Satellite visualisation
- Map View visualisation

- Bathymetry visualisation

The Satellite visualisation shows the surface of the Earth as pictures taken from a satellite (see Figure 3).

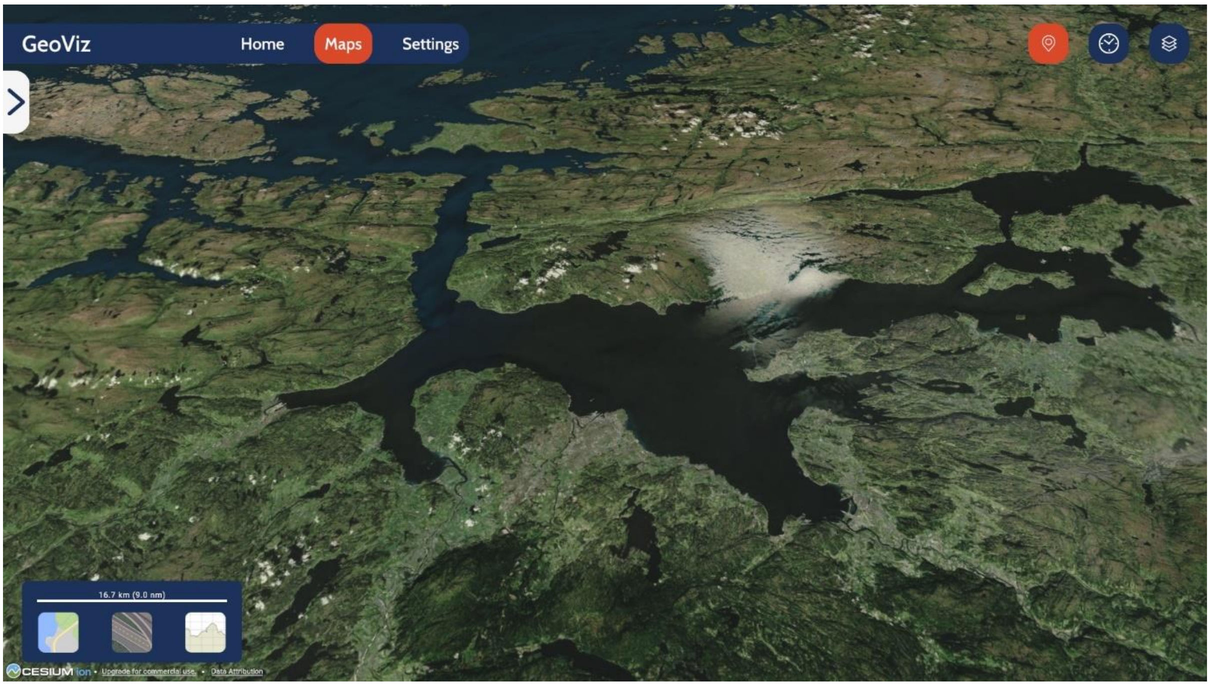

Figure 4: Satellite visualisation of the Earth.

The Map View visualisation shows the surface of the Earth similarly to how many "maps" mobile applications do: using blue for marine areas, light-grey or green for land areas, and including main roads and urban areas and some toponyms (see Figure 4).

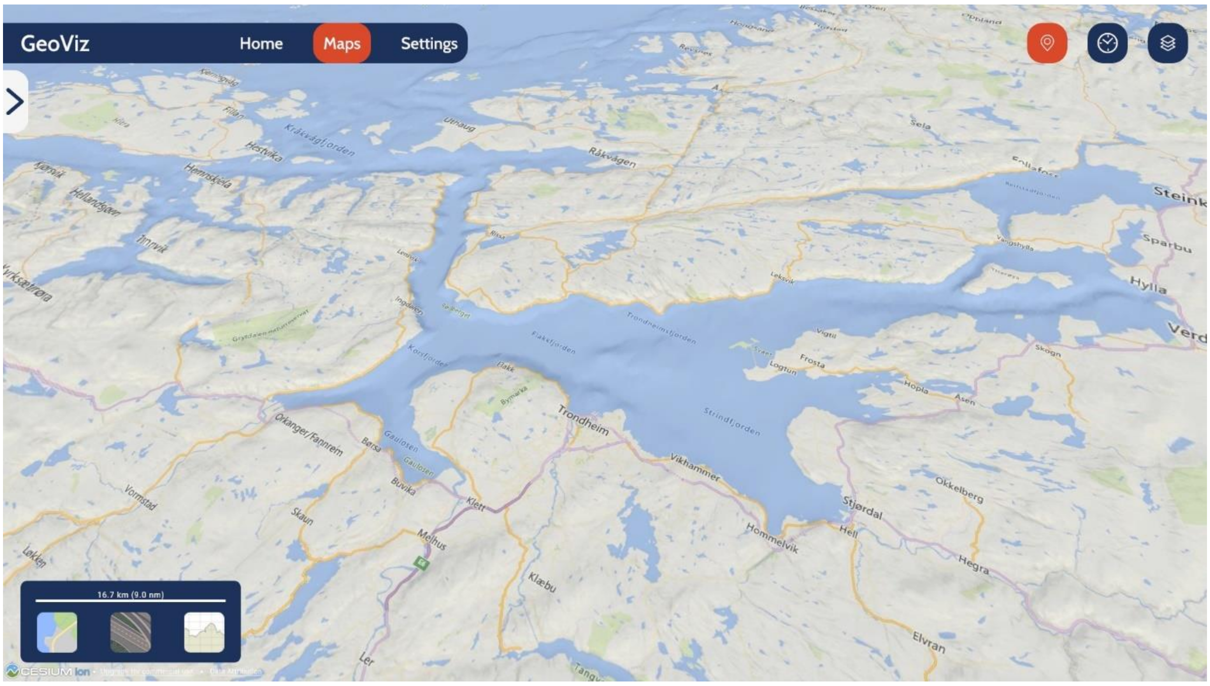

Figure 5: Map View visualisation of the Earth.

The Bathymetry visualisation shows the surface of the Earth with the scientific representations of the change of altitude, from the mountains on land to the bottom of the sea basins (see Figure 5).

Figure 6: Bathymetry visualisation of the Earth.

The map selection window contains also a ruler showing the real distance in kilometres of visualised distances, as a scale bar.

2.2.2.3 Camera Controller

It was decided to provide to the user a seamless experience in navigating through a 2D and 3D visualisation.

It is in fact possible to keep the 2D top-down visualisation by clicking and dragging through the map.

To move freely in 3D, it's sufficient to use the keyboard's arrows or "WASD" keys, while orientating the camera holding the right mouse button and moving around.

The position of the camera will be centred on top of the particles as soon as the data are loaded into the application (see Figure 6). Moreover, the user will be able to reset the position of the camera on the origin of the particles by pressing the "R" key on the keyboard at any time.

A detailed guide of the controls for the camera will be included as a pdf file inside the downloadable build archive.

When the camera height drops below the level of the sea, a blue filter is applied, to convey to the user the idea of being under water.

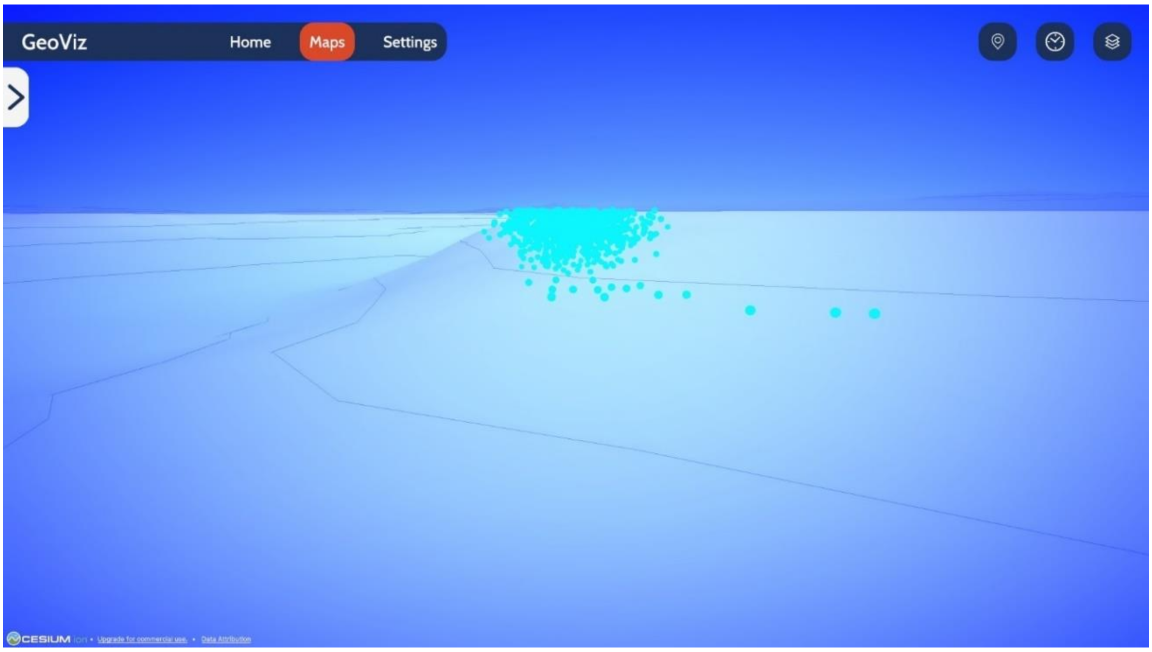

Figure 7: Underwater visualisation of particles.

2.2.2.4 Data Loader

Most of the interactions with the simulation of the particles are accessible through the collapsable "Left Bar".

The first section contains the "Load File" button that allows the user to browse his computer and select a NetCDF file (.nc extension) containing the data that they want to visualise (see Figure 7).

Once the file is selected, it will be parsed using the SDS library mentioned in section 2.1.2. The file must respect the supported structure to be parsed correctly. More details on this aspect will be discussed in chapter 3.2 dedicated to the possible extension of the application.

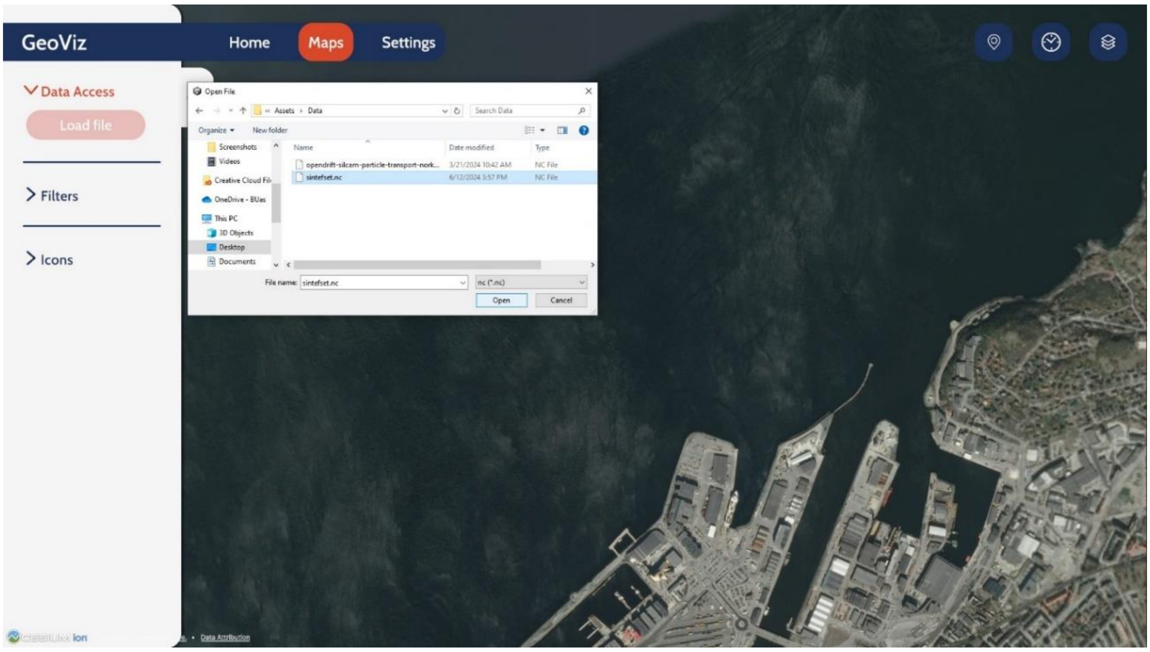

Figure 8: Selection of NetCDF file from the application.

2.2.2.5 Data filtering

The second section allows the user to filter the particles and to code them.

This is where we use the Particle type and size are used to convey additional information through the visualisation of the particles.

It is possible to enable/disable the visualisation for specific types of particles, to limit the range of diameter to be visualised and/or limit the range of depth to be seen.

The diameter of the particles and their depth, being numerical values, can be filtered at runtime through bidirectional sliders, limiting the maximal and minimal value to be visualised.

The type, being discrete, can be toggled on and off using a list of toggles.

The thresholds for the numerical values, and the toggles in the list are automatically filled using the information contained in the NetCDF file.

2.2.2.6 Data coding

The second interaction the user can have with the particles, within the same second section "Filters" is coding them using colour or darkness on one of the variables available for filtering.

This means that the user can, for example, convey the depth of the particles using their darkness and their diameter through a range of colours.

A Legend window is dynamically filled depending on the type of coding being applied to the particles (see Figure 8).

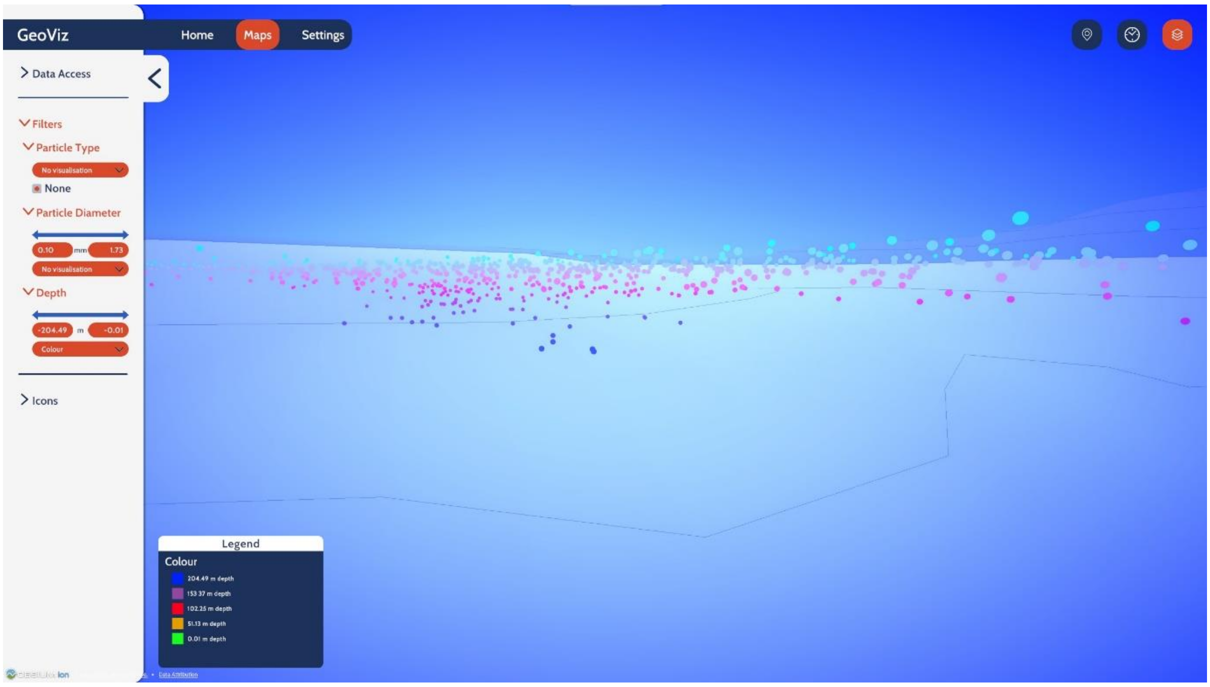

Figure 9: Visualisation of the depth of the particles through colour coding.

2.2.2.7 Data sources

The last section of the Left Bar, called "Icons", allows the user to setup the location of their data sources using latitude/longitude coordinates (see Figure 9).

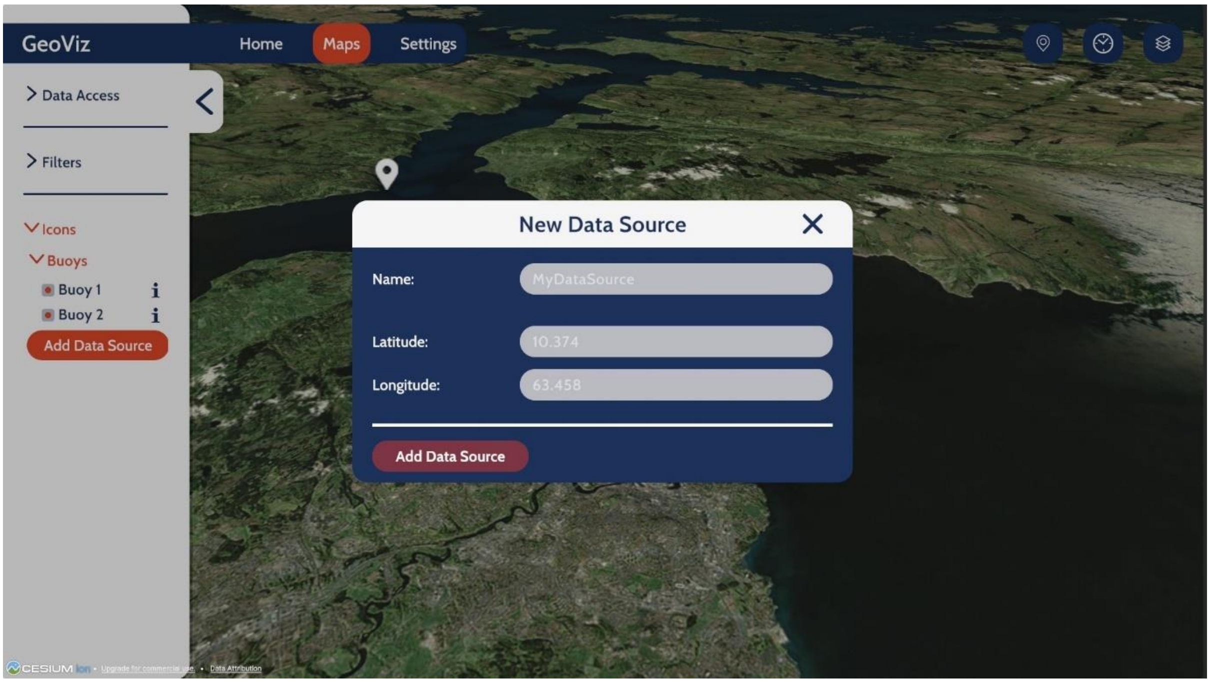

Figure 10: Pop-out window to setup a new data source.

The data source will then be added to the list of toggles under the Icons section and will be visualised with a small icon at the specified position in the world (see Figure 10).

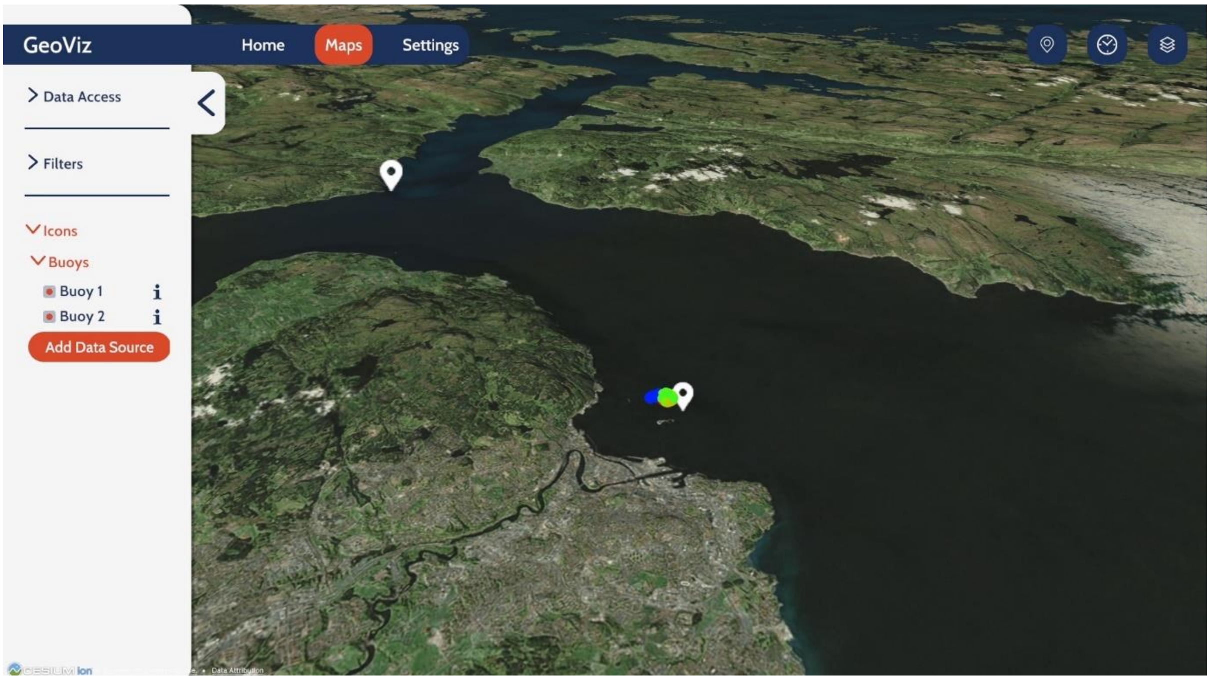

Figure 11: SINTEF buoys visualised on the map.

2.2.2.8 Simulation Controller

The simulation is controllable by the user through the "simulation time control" window, accessible through the "Clock" icon on the upper-right side of the application. This window contains a bar dynamically showing the progress of the simulation on the provided timeframe window of the data, and three buttons to control the speed of the simulation (see Figure 11):

- Pause button

- Play button
- Fast-forward button

The user can play the simulation at different speeds by pressing multiple time the fast-forward button, up to 8x the normal speed.

Figure 12: Simulation sped up to 4x.

2.2.3 Settings Page

The last page of the application is the Settings page (see Figure 12).

This page allows the user to customise the application video settings to their liking.

The fullscreen resolution of the application can be selected from a scrollable dropdown menu, which is automatically populated with all the resolution supported by the screen in use.

The user can also decide to use the application in windowed mode, by disabling the "Fullscreen" toggle.

In this way the size of the window can be dynamically changed by the user by dragging the borders of the window. When in this mode, the resolutions dropdown is disabled.

Most of the UI elements used in the application dynamically scale with the window size. However, while the manual resizing offers infinite possibilities for the user, it is not guaranteed that all elements will always display as expected in fullscreen mode.

From the setting page the user can close the application by pressing the "Exit Application" button.

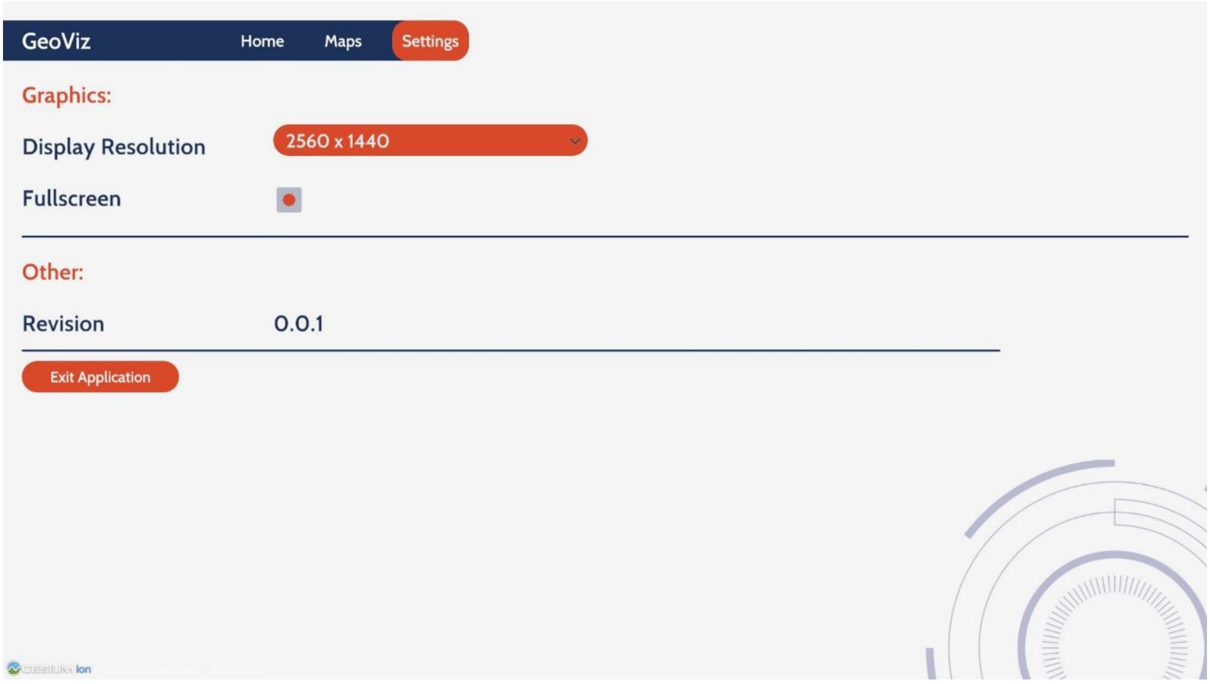

Figure 13: The Settings page.

2.3 Development methodology

In D6.6 it has been declared the intention of following the Scrum AGILE methodology to pursue the delivery of a final application respecting the will and vision of the main involved stakeholders. In accordance with the principles and rituals of this methodology, a recurring technical demo was held by BUas with SINTEF, to show the continuous development and progress of the application, and to gather direct feedback so that the development could be steered reasonably to match the desires of the stakeholders.

This recurring meeting was also an opportunity for BUas to determine which data format the application should support, and which information were provided by the owner of the data that could be used to improve the visualisation and interaction ability of the application.

A total of six demo meetings were held from September 2023 to June 2024, with the recordings of these demos made available only for partners use.

3 Licensing, personal use, future development

3.1 Licensing

It was agreed internally by BUas to use the GNU General Public License Version (GPL-3.0-only) license.

The code is accessible on GitHub and can be cloned by anyone interested in delving in the technical aspect of the application (https://github.com/BredaUniversityResearch/MicroparticlesVisualization-ILIAD/releases/tag/1.0.0).

An Iliad Marketplace webpage (https://ocean-twin.eu/marketplace/product/geoviz) has been created, describing the scope and features of the application, and redirecting to the GitHub repository of the project, where any user will be able to download the latest release and use it to visualise their data.

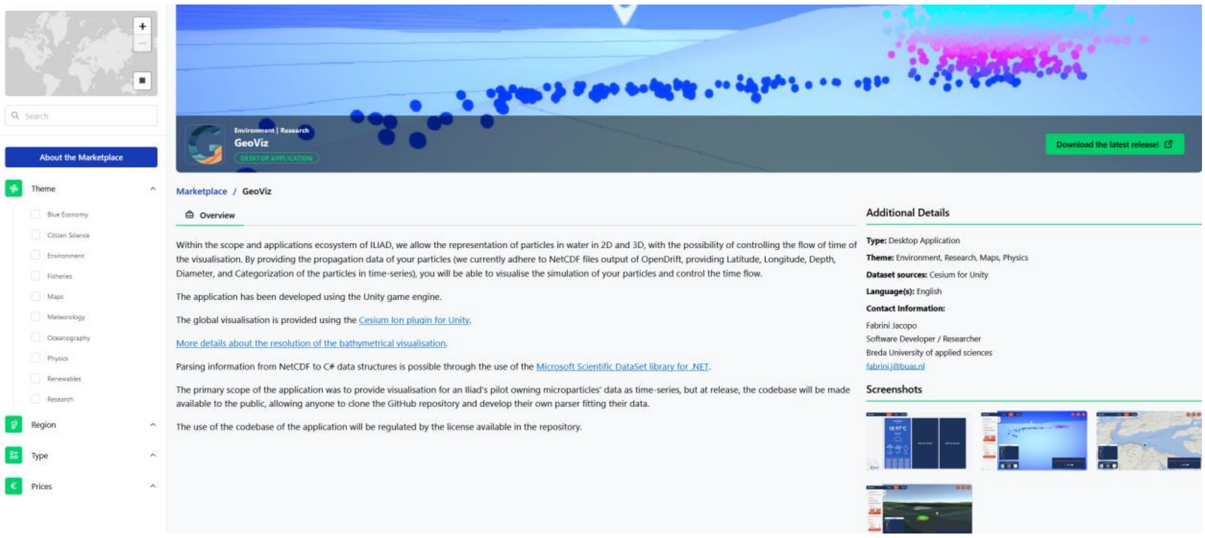

Figure 14: GeoViz application page in the Iliad Marketplace

3.2 Use for personal data visualisation

The parsing process from NetCDF to .NET data structures is detailed in the "DataLoader.cs" file of the project.

Any user that would like to visualise personal data will be able to do so in two possible ways:

- Respecting the data format already defined in the aforementioned .cs file.
- Clone the repository, modify the DataLoader.cs file to their need, and generate a new build.

The first possibility simply requires the user to act on their NetCDF file, to make sure that the data contained in it respects the format and naming defined in the code delegated to parsing.

The second possibility requires the user to act on the codebase of the application itself by creating a local development setup and modifying the parser file.

3.2.1 Local development setup

As mentioned earlier, anyone can access the codebase and modify it locally but, in order to do so, and to be able to generate a build, there are some steps that need to be followed to make sure the local development setup works correctly.

- The user must have Unity 2022.3.20f1 installed to open the project and edit it.
- The user must set up their own API token for Cesium.
- The user must have their own API token in "Assets/Secrets/OpenWeatherAPIKey.txt" to have the weather widget working.
- Clone and pull the submodules to retrieve the Cesium plugin that is being used by the application.
- Two paid Unity plugins are being used in the project, and for their license their code cannot be made available, for this reason the user must buy the following plugins and put them in the "Assets/Plugins/GeoViz_Private_Plugins" folder of the project:
    - Odin Inspector and Serializer (Sirenix)
    - File Browser PRO (Crosstales)

These steps are detailed also in the README.md file in the repository.

While creating a local development setup is a more complex possibility than simply changing the input NetCDF file, it would allow the user to have complete control on the application, its parsing and visualisation processes, enabling them to effectively modify and extend their application freely to their need as long as the licensing is respected.

3.3 Future developments

It is possible to foresee two possible ways for the GeoViz application to be further developed:

- The first way is external; thanks to the licensing of the project, anyone can contribute to further development by forking the repository on GitHub, making changes and creating a Pull Request to the development branch. If the changes will be reviewed as useful and improving the generic user experience, then they will be merged on the development branch by a member of the BUas' development team.
- The second way is internal, but it will happen only if more budget for development will be found through new projects.

Thanks to Iliad webinars where the application was presented, it was clear that there is a variety of institutions, research laboratories, companies that might be interested in using GeoViz as a tool to interact and visualise their data.

One main direction of development that could be taken in the future could be the simplification of the intake of data, making the NetCDF parser as generic as possible, guaranteeing the intake of any structure, and allowing the user to select which variables they would like to visualise on the particles.

These features would improve the user experience and widen the use cases for the application.

4 Conclusion

GeoViz stands as a testament to the innovative spirit and collaborative efforts of the Iliad project. It offers a powerful tool for visualising marine and maritime data, enhancing our ability to understand and manage marine environments. The application's success is evidenced by its advanced visualisation capabilities, user-centric design, and adherence to scientific standards.

As the project progresses, continued development and community engagement will be vital in realising the full potential of GeoViz. By simplifying data ingestion, extending functionality, and fostering an active user community, GeoViz will remain a valuable asset for both scientific research and practical applications. The commitment to open-source principles ensures that GeoViz will continue to evolve, driven by the collective efforts of a global community.

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