Immersive Visualization Metaverse for EO Applications

Demonstrate the potential of extended reality, immersive visualization and metaverse for EO uses cases

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The Visu4EO Platform

The **Visu4EO platform** allows users to simultaneously define and manipulate various parameters, to simulate different scenarios scenarios and planning decisions, to evaluate their impact on urban mobility **in an Immersive Visualization Experience.**

The application allows navigating a **3D model of the scenario** visually simulating conditions and using **VR advanced techniques** to seamlessly transport the user from the space to the local scale.

This truly immersive experience implements **an innovative and advanced support for policy and decision makers**, that can experience and evaluate the effects of decisions profiting from the sense of wonder (**the "WOW factor"**) and the empathy that VR technologies can foster in users.

By simulating **various scenarios** and their **impact on mobility**, city planners can identify vulnerabilities and develop strategies to **enhance the resilience** of urban transportation networks.

Demonstration Scenario: Copenhagen

Flooding risk in Denmark is significantly influenced by climate change and land cover changes, which interact to exacerbate both coastal and inland flooding. Climate change is causing **increased heavy precipitation**, with more frequent and intense rainfall events becoming the norm. Additionally, **global sea levels are rising** by an average of 3.5mm per year, enhancing the severity of storm surges, particularly in low-lying coastal areas.

Urbanization further exacerbates flooding risks as the conversion of natural areas to agricultural or urban land cover leads to an expansion of impervious surfaces, reducing soil permeability, increasing runoff, and thus heightening flood risks.

Flooding can cause **severe disruptions to urban mobility**, impacting traffic flows, congestion levels, and travel times. **Effective mobility planning** involves creating **resilient infrastructure** and implementing appropriate **traffic management strategies** to minimize the impact of floods on mobility.



Visu4EO Simulation Parameters

The Visu4EO platform allows users to simultaneously define and manipulate various parameters to **simulate different flood scenarios and urban planning decisions** and evaluate their impact on mobility.

Flood-Related Parameters

Rainfall Duration and Intensity: Users can set the duration of rainfall from 1 hour to 72 hours of uninterrupted rainfall and can adjust the rainfall intensity within a range of 15mm to 150mm.

Sea Level Rise: Users can input sea-level rise projections based on the IPCC's Sixth Assessment Report (AR6) climate scenarios.

Land Use Policies: Inland Water, Urban Areas, Forests, Agricultural Areas, Non-Forested Natural Areas

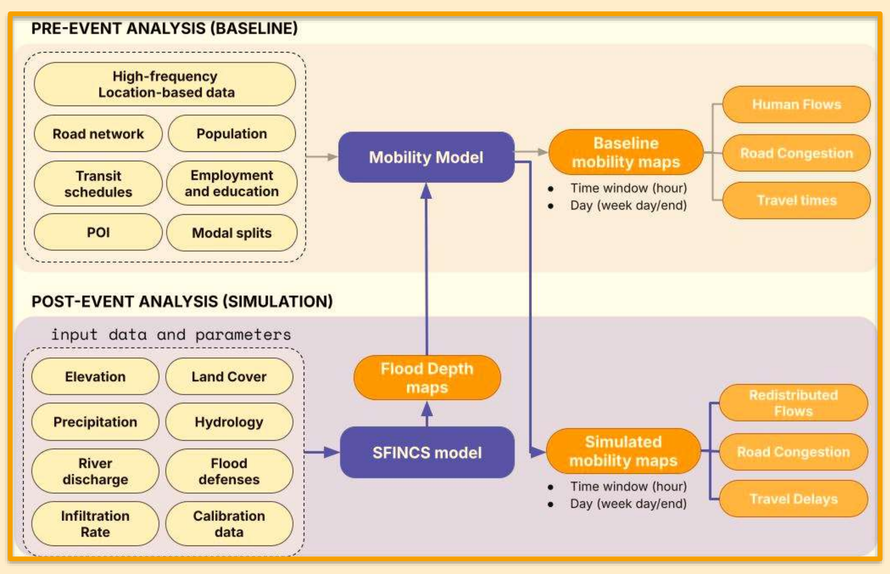
Flood Defense Systems: Thin Dams, Weirs, Drainage Pumps, Culverts

Mobility-Related Parameters

Road Network Changes: Road Segment Conversion, Average Speed Adjustment, Road Segment Accessibility

Point of Interest (POI) Management: Adjusting the number of POIs across various categories within the simulation.

Population Dynamics: Adjusting population levels to reflect increases or decreases in the simulated area to understand how population density changes influence traffic flow and congestion.



Simulation Engines

Deep Gravity Model

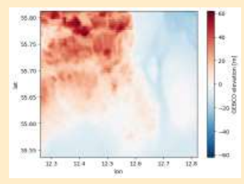
AI-based model leveraging DL to process vast datasets and uncover complex mobility patterns. It can generate origin-destination (OD) matrices as outputs for specific mobility scenarios **simulating flows between locations** for any urban agglomeration by leveraging information such as tessellation, population distribution, and travel demand data.

SUMO - Simulation of Urban MObility

Developed by the Institute of Transportation Systems at DLR, SUMO is an **advanced, open-source traffic simulation package** designed for microscopic and continuous traffic modeling in large networks. SUMO is specifically designed for microscopic and continuous traffic modeling in large networks, supporting intermodal simulation that includes pedestrian traffic. SUMO provides a comprehensive toolkit for detailed analysis of traffic flows in complex urban environments, creating realistic traffic demand profiles.

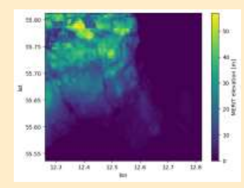
SFINCS - Super-Fast INundation of CoastS

Developed by Deltares, SFINCS is designed for the **dynamic simulation of compound flooding in large-scale coastal systems.** It balances high computational efficiency with accuracy, making it valuable for rapid and large-area flood assessments. SFINCS can perform quickscan computations of coastal, riverine, and urban flood scenarios, providing critical insights for early warning systems and multi-hazard risk analyses.



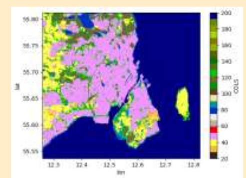
MERIT Hydro

Global flow direction map at 3 arc-second resolution (~90 m at the equator). Automatically extracts accurate river networks with minimal manual edits. High accuracy: <5% error in 90% of drainage areas. Covers 90N to 60S with improved small stream representation.



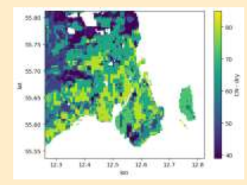
GEBCO 2023 Grid

Global terrain model for ocean and land at 15 arc-second resolution (~1 km at the equator). Pixel-centered elevation data values , (they refer to the elevation at the center of each grid cell). Includes land, ice surface elevation information. Used only for areas below sea level and can be overlaid with MERIT data for complete coverage.



Global Land Service (CGLS-LC100)

Provides global bio-geophysical data on land surface status and evolution at 100 m resolution. Includes discrete land cover classes and continuous field layers for proportional vegetation/ground cover estimates. To be used for estimating roughness parameters. Data covers 2015-19 (annual updates planned from 2020).



ERA5 Data for Hydrological Flood Modeling

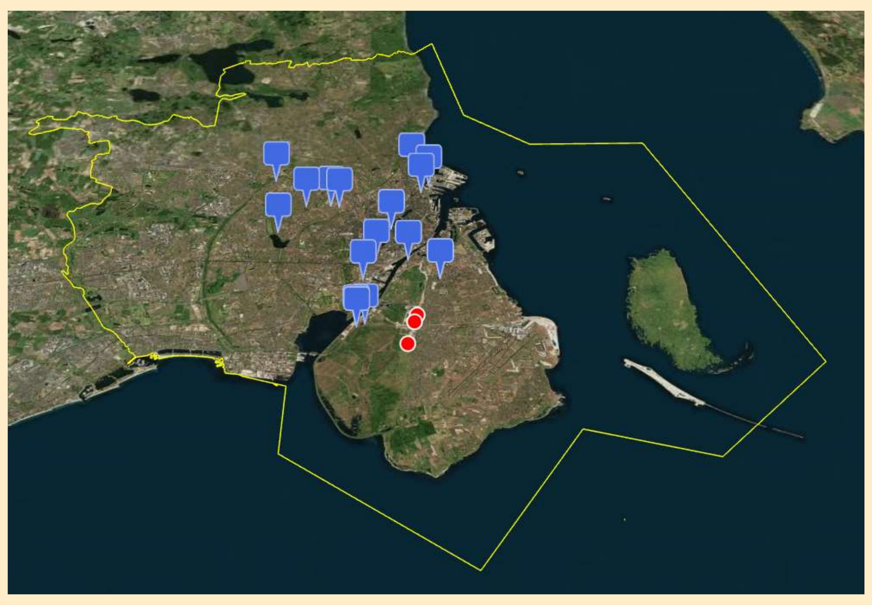
Global reanalysis dataset by ECMWF, ~31 km resolution, hourly data. Supports runoff and river flow simulations using precipitation data.

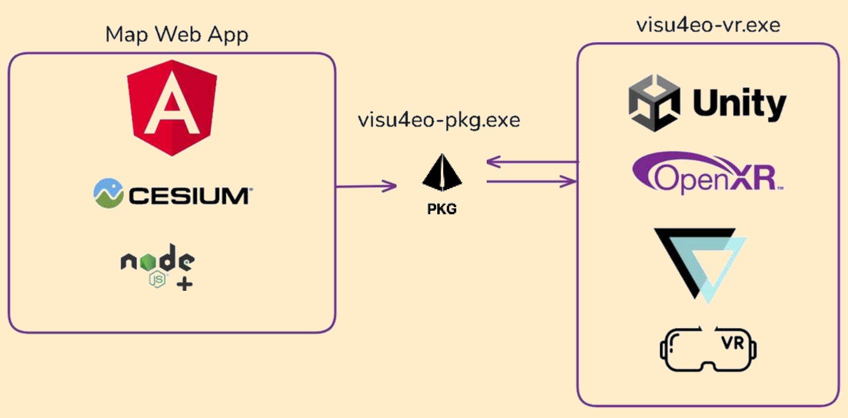
Visu4EO Immersive Experience

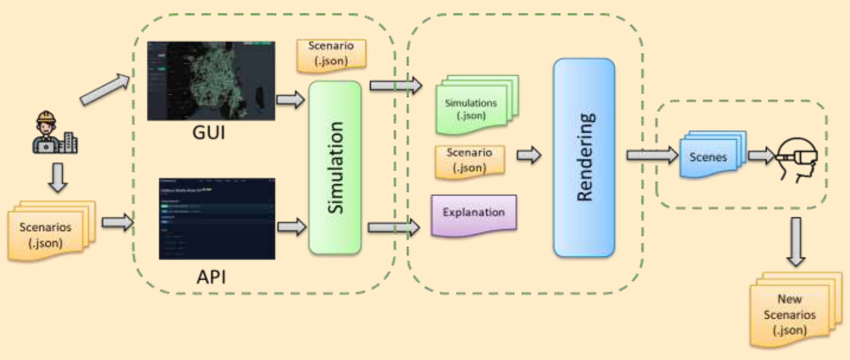
The **Visu4EO VR App** will render a dynamic scene based on the simulation data received from the model.

This simulation is based on the City of Copenhagen during a hydrogeological emergency relating to floods and overflows as a function of the amount of rain that falls in certain periods of time.

Starting from the map view we give the user the choice to select one of the many points of interest selected for the rendered scenes.







VR Technologies for Visu4EO

The VR Technology proposes a mixture of web technologies, the **3D WebView** component for Unity and **CesiumJS** for globe visualization, plus **Blender** (Blosm Plugin) to model the areas of interest. The proposed solution is completed by **the XR Interaction Toolkit**, an a high-level, component-based interaction system for creating VR and AR experiences in Unity.

This solution simplifies 3D and UI interactions by providing a framework that integrates with Unity input events. The 3D WebView is meant to be used to open a 3D view in the VR Technology, where CesiumJS is used to render the map.

VR Scenarios

The **Visu4EO VR App** renders scenarios based on the simulation data.

Predictions of the **city flooding** based on the quantity of rain fallen. Rivers and canal flooding, sewer system for the water discharge, etc..

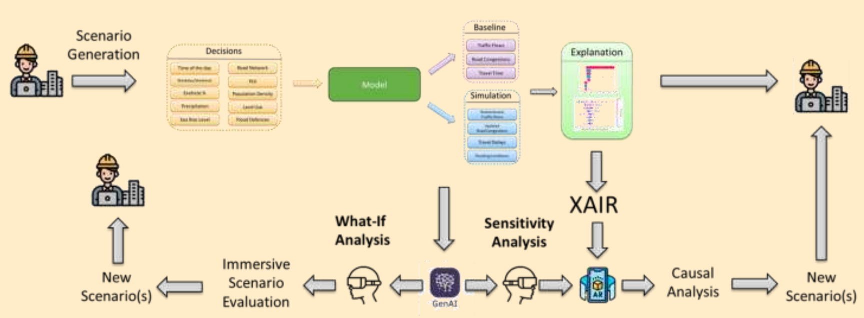
Traffic predictions. During a flood and what will happen in the city in relation to the traffic flow.

Predictions on **people's behaviour** during a flood catastrophic event. Road closure based on a **threshold of water quantity** in case of a flood. How would the city look like and what are the **environmental impacts.**

While using the app the user has the possibility to control and generate these simulations using the UI (user interface).

What-If and Sensitivity Analysis

A scenario is defined by a user as a set changes on the baseline map that a user wants to simulate (like flooding barriers or levels of rain to be simulated). Once that a scenario is simulated and an explanation is generated, the simulation outcomes and the explanations are used to render scenarios for the VR, using GenAI to simulate the flooding effects. For what-if analysis, the user can have an immersive experience in the simulation, being able to **evaluate the scenario and take decisions that will then be used to generate new scenarios.** For causal analysis, the explanation is used to provide the user **actionable knowledge during the immersive experience**, trough the XAIR Framework that provides hints on what to explain, when and how. This information will allow the user to get informed about causal relationships between the decisions that define the scenario and simulation outputs. This analysis is then used by the user to define new scenarios.

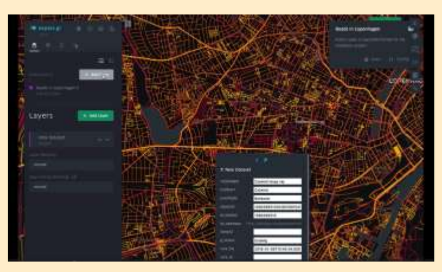


Scenario Definition

A GUI based on kepler.gl is provided to **define scenarios and analyze simulation results.** The user works with maps where parameters can be defined for **road segments and grid hexagons.** Parameter values can be changed and/or selected to define simulation scenarios.

Road segments are labelled with information **about street type, traffic allowed, maximum speed, flood defenses** and others. For grid hexagons the user can define **Points of Interest in that area, land usage policies and population dynamics.**

General **mobility and flood related parameters**, like percentage of bicycles and electric vehicles in circulation, time of the day, type of day (weekday or weekend), rainfall duration/intensity and sea level rise complete the scenario definition.




Explainable AI: Analysis and Support

Model validation and increase trustworthiness

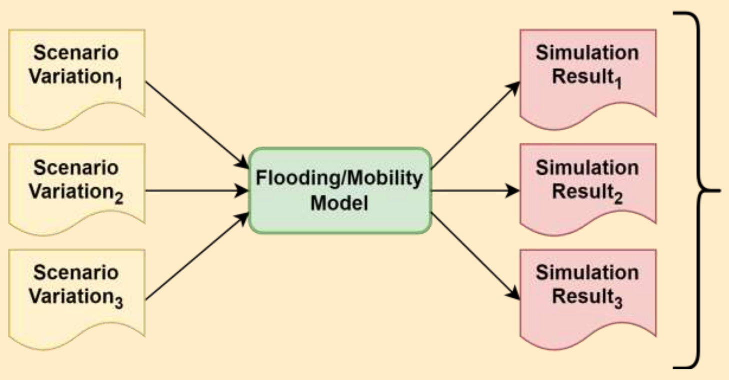
Ensures algorithm transparency as well as global interpretability of the model and helps the users understand how the model is working and how the system makes predictions depending on the input by providing insight into intermediate processing steps of the simulation.

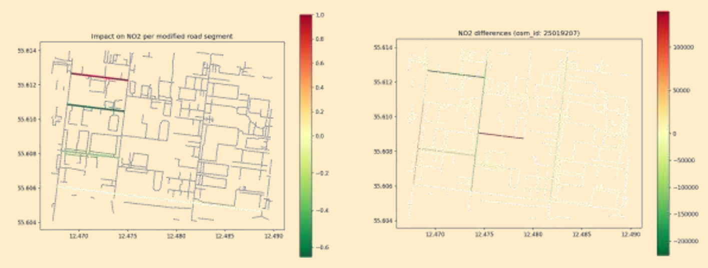
Root cause analysis and explanation

Explains how individual user decisions affect the local environment both as a difference view when assuming not making this decision as well as compared to other decisions in a normalized view. That way the users learn which of their decisions result in an overall positive outcome and which are worth looking for improvements.

Intelligent assistance and decision-making support

Provides concrete suggestions on how to improve individual decisions and optimize their parameters in order to approach an ideal solution under the given circumstances by simulating possible variations of individual user decisions and evaluating their outcome.





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