Artificial Intelligence and Earth Observation towards Disaster Risk Reduction: The AI-OBSERVER's research exploratory project

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ABSTRACT

The AI-OBSERVER project has received funding from the European Union's Horizon Europe Framework Programme HORIZON-WIDERA-2021-ACCESS-03 (Twinning) under the Grant Agreement No. 101079468. The project started in October 2022 and has a duration of 36 months. The ERATOSTHENES Centre of Excellence (CoE) for Earth Observation, Space Technology and Geoinformation is the project coordinator, and the consortium also consists of two internationally leading research institutions, the German Research Centre for Artificial Intelligence (DFKI) from Germany and the University of Rome Tor Vergata (UNITOV) from Italy, and an industrial partner CELLOCK Ltd from Cyprus. With AI-OBSERVER project being currently in its last year, the efforts of ERATOSTHENES CoE are focused on the development of six risk assessment models for multi-hazard monitoring and assessment in Cyprus on i) Earthquakes, (ii) Landslides, (iii) Coastal erosion, (iv) Forest fires, (v) Floods and (vi) Marine Pollution. These are being developed by applying the enhanced skills and scientific background ERATOSTHENES CoE's researchers acquired on the application of advanced Artificial Intelligence (AI)-based techniques on Earth Observation (EO) and geospatial datasets, via the various capacity building activities carried out during the 3 years of the project by the advanced partners, i.e., the German Research Centre for Artificial Intelligence (DFKI) from Germany, and the University of Rome Tor Vergata (UNITOV) from Italy. The overall methodology for these six models and some initial results are presented in this study.

Keywords: Artificial Intelligence, Earth Observation, Disaster Risk Reduction, Environmental Hazards, Risk Assessment, GeoAI

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1. INTRODUCTION

In the last decades, Earth Observation (EO) datasets have been widely used with many applications in various domains [1-3]. The availability of a vast amount of satellite data from the freely available Copernicus program as well as from a great number of commercial satellite data providers, has increased the need for the development of methodologies that can utilize these big data and provide valuable insights to researchers and decision makers. Due to Climate change, there is an increased need of using these datasets to develop products in the domain of disaster risk reduction and disaster management, where the provision of data in a timely manner is of great importance [4-6]. Advanced data processing techniques utilizing Artificial Intelligence (AI) have not only enhanced data processing capabilities but also the accuracy of EO-based results, facilitating their adoption by various stakeholders [7-9].

In this context, the AI-OBSERVER project received funding from the European Union's Horizon Europe Framework Programme HORIZON-WIDERA-2021-ACCESS-03 (Twinning) under Grant Agreement No 101079468 [10, 11]. The project aims to significantly strengthen and stimulate scientific excellence and innovation capacity on the topic of AI used on EO for Disaster Risk Reduction, as well as the research management and administrative skills of the ERATOSTHENES Centre of Excellence (CoE) [12, 13]. The ERATOSTHENES CoE, an autonomous and self-sustained

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Centre of Excellence envisioning to become a world-class digital innovation hub for Earth Observation, space technology and geospatial information in the Eastern Mediterranean, Middle East and North Africa (EMMENA) [14], is the project coordinator. The consortium also consists of two internationally top-class leading research institutions, the German Research Centre for Artificial Intelligence (DFKI) from Germany and the University of Rome Tor Vergata (UNITOV) from Italy, and an industrial partner CELLOCK Ltd from Cyprus.

In this study, after an introduction to the study in section 1, the methodology and data used for the development of the six combined AI-EO risk assessment models is presented in section 2, the initial results and their discussion are included in section 3, and the conclusions as well as next steps are showcased in section 4.

2. DATA AND METHODOLOGY

In the framework of the project, and through other networking activities of the ERATOSTHENES CoE, numerous meetings have been organized with various stakeholders, i.e., the Cyprus Civil Defence, the Geological Survey Department, the Public Works Department, the Department of Forests, the Water Development Department, etc., to collect their requirements in terms of disaster risk assessment and mapping. Based on these recorded needs, ERATOSTHENES CoE collected the data required as input to the EO Big Data AI management platform, developed by CELLOCK Ltd, that will be used for the risk assessment of environmental hazards, exploiting various data sources.

Following the meetings with stakeholders and the identification of their requirements, the areas of interest were identified, and the data needed to carry out the analysis for each one of the six hazards were collected from multiple sources in various formats. In fact, meteorological data, geological maps, Digital Elevation Models (DEM), historical data, inventories, risk maps, etc., collected from local stakeholders, were used to feed the AI-EO risk assessment models.

Moreover, satellite optical and Synthetic Aperture Radar (SAR) images, provided freely by Copernicus (Sentinels), and other European Space Agency (ESA) Third Party Missions (Planet) were also used for the monitoring and calculation of other hazard contributing factors (soil moisture, slope, vegetation, etc.). Finally, other EO-based thematic services, such as the CORINE LULC and the ESA WorldCover, Copernicus Services (EMS, LMS, etc.) and Thematic Exploitation Platforms (F-TEP, G-TEP, etc.) were used to retrieve valuable information regarding some of the environmental hazards' contributing factors.

Following their development, the risk assessment models will then be integrated into an EO Big Data AI management platform, leading to the development of the first ERATOSTHENES CoE product integrating EO and AI for Disaster Risk Reduction. A route to market strategy will also be formulated for the exploitation of the project's outputs and developed platform, and the results will be presented to an open to public workshop, that will be carried out by the end of the project. This event will be attended by all end users/stakeholders, to maximize the project's visibility. The overall methodology is presented in Figure 1 below.

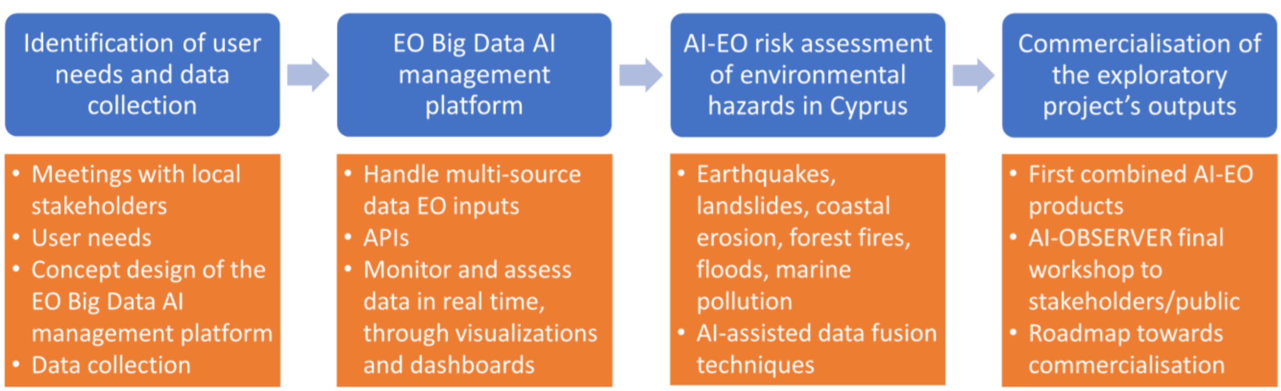

Figure 1. Methodology implemented during the exploratory research activities of the AI-OBSERVER project. The methodology included the identification of user needs and the collection of data; the development of the EO Big Data AI management platform, the development of combined AI-EO risk assessment models for environmental hazards; and the commercialization of the project's outputs.

3. RESULTS AND DISCUSSION

Following the various meetings that the ERATOSTHENES Centre of Excellence had with these stakeholders, their requirements were collected for each hazard. Based on these, the risk models are being designed to accommodate where possible these identified user needs. Their needs ranged from damage and impact assessment, risk mapping, vulnerability assessment, optimization of resource allocation, suggestion of prevention measures, policy recommendations, etc.

Working Groups were formed for each environmental hazard, consisting of researchers from ERATOSTHENES Centre of Excellence, University of Rome Tor Vergata and the German Research Centre for Artificial Intelligence. They defined concrete milestones, from the analysis of user requirements and data collection to the development of risk assessment models for earthquakes, landslides, coastal erosion, forest fires, floods and marine pollution. Through this approach, case studies were selected for each environmental hazard based on discussions with relevant stakeholders. A variety of Artificial Intelligence and Machine Learning methods were applied, which were made available through the various capacity building activities.

Figure 2. The AI-OBSERVER exploratory research project and its objectives towards advancements in preparedness, mitigation, response, recovery and prevention against earthquakes, landslides, coastal erosion, forest fires, floods, and marine pollution.

Regarding earthquakes, an AI-based algorithm is under development to assess earthquake vulnerability at critical infrastructure in Paphos District, Cyprus. The process includes an initial vulnerability estimation based on the infrastructure's vulnerability characteristics, and incorporates AI and image processing techniques to determine structural condition and climate-induced degradation state using street level images of structural and non-structural elements, e.g., beams, columns, infill walls etc. Damage levels are then identified and correlated with extensive image databases. Damage is then identified using the structure's image incorporated into AI-based algorithm, and the vulnerability status is updated based on new damage insights.

Landslide risk assessment is performed using satellite and auxiliary data (DEM, Slope, Aspect, Precipitation Data, Lithology, Faults, Relief, Road Network, Streams and Land Use). Precipitation data (CHIRPS) were collected and used as the training dataset for the AI algorithm to fill the gaps of rainfall data from rain gauges in areas with no or limited data. A Multicriteria Decision Analysis (MCDA) is then performed to calculate landslide risk at the area of interest.

Regarding coastal erosion, satellite data from the Sentinels (Copernicus) and Planetscope were used for temporal coastal change monitoring. Moreover, UAV images are used for detailed shoreline analysis, whereas coastline shapefiles were used for shoreline delineation and erosion/accretion mapping. Last but not least, GNSS ground truth points were used for validating remote sensing analysis. AI diffusion models are being currently applied for the prediction of the near future based on historic pattern derived from time series of satellite images.

Furthermore, a multidimensional dataset based on satellite spectral bands, spectral indices, and auxiliary data (elevation, slope, aspect, tree density, etc.) has been developed for forest fires. As a first step, the Fuel Type Scheme preparation was conducted using the Fire Behaviour Fuel Models (FBFM) provided by Scott and Burgan Fire Models [15], and the collection of the corresponding samples. High-resolution images from Google Earth and the georeferenced digital aerial ortho-photos provided by the Department of Lands and Surveys for the years 2014 and 2019 were also used for photo interpretation, which are accessible as a base map in ArcGIS software. The data were collected, primarily to cover the entire region of Cyprus (excluding the occupied areas) with a strong emphasis on forested areas, and to improve the performance of the algorithms.

For flood risk assessment, a Multicriteria Decision Analysis (MCDA) was performed to calculate flood risk at the area of interest. A Convolutional Neural Network (CNN) was developed utilizing various data from multiple sources, such as terrain elevation, slope, flow accumulation, land use/land cover, soil, rainfall intensity, etc. The results were then compared to the flood-inventory map provided by the Water Development Department.

Moreover, for marine pollution monitoring, data sourced from the northern Mediterranean shore of Egypt (El-Alamein to Al-Arish), including cities like Alexandria, Rashid, and Port Said, were collected, as these areas have similar coastal features with Cyprus, with no impact on oil spill detection. Additionally, sea depth and average temperatures in both regions do not hinder detection, as well as atmospheric conditions, such as humidity and pressure, have minimal effect on detection. A CNN/U-Net was developed for oil spill detection, creating oil spill polygons and calculating their areas.

By the end of the project, the developed risk assessment models will be integrated into an EO Big Data AI management platform, leading to the development of the first ERATOSTHENES CoE product integrating EO and AI for Disaster Risk Reduction. In addition, a marketing strategy to exploit the project's results and the developed platform will be formulated to maximize the project's visibility.

4. CONCLUSIONS

The extensive series of capacity building that was carried out by the advanced partners to ERATOSTHENES Centre of Excellence staff has facilitated the adoption of innovative Artificial Intelligence-based techniques in processing and integrating data from multiple sources. Moreover, apart from the disaster risk reduction domain, that the AI-OBSERVER project is oriented, researchers from other clusters and departments of the Centre have adopted these techniques and are using them in their processing pipelines. This has led to an increased number of publications, reaching over 10 submitted in peer-reviewed journals and international conferences [12,13,16-23].

In the context of the exploratory research project activities, it is the first time in Cyprus, that a project deals with the integration of AI and EO, and the collaboration with the two leading institutions, i.e., the German Research Center for Artificial Intelligence and the University of Rome Tor Vergata, provides added value to produced results. Currently, the processing pipelines are being fine-tuned, and the models are being trained to increase the accuracy of their produced results. The developed models will then be integrated into the EO Big Data AI management platform, currently under development by CELLOCK Ltd. The models and results are expected to be presented to stakeholders and end-users in a public event in September 2025, to increase the visibility of the project, its results, and the ERATOSTHENES Centre of Excellence itself.

As next steps, and towards the achievement of the long-term commercialization goals of the AI-OBSERVER project and ERATOSTHENES CoE, the produced models will be trained further to be able to produce reliable results on a national level, and efforts will be made to transfer these to other countries in the Eastern Mediterranean, Middle East and North Africa region.

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