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Development of a Decision Support System for Improved Resilience & Sustainable Reconstruction of historic areas to cope with Climate Change & Extreme Events based on Novel Sensors and Modelling Tools

This work is a part of the HYPERION project. HYPERION has received funding from the European Union's Horizon 2020 research and innovation programme under grant agreement no 821054.

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Editorial by HYPERION Project Coordinator, Dr. Angelos Amditis

Dear readers,

I am pleased to welcome you to the 1st issue of the HYPERION Magazine! An annual publication of the project created to present the project's major results and achievements, through its first year of activities. In the aftermath of the COVID-19 pandemic and despite the restrictions imposed, the HYPERION team stayed connected and continued to work together, remaining physically distant, to build knowledge and to carry out our vision for promoting the sustainable preservation of cultural heritage around the world. Resilience is an essential attribute as we move through this crisis and into the future. Climate Change, ravages of time, intense geological phenomena and accidental, extreme weather conditions, all take a heavy toll on historical areas hosting Cultural Heritage sites. Started in June 2019, HYPERION continues for 4 years, being financed by European Union's Horizon 2020 research and innovation programme, with the expectation to address these challenges and bring major impact on the conservation-restoration and safeguarding of tangible cultural wealth. Using novel tools, services and technologies, HYPERION consortium will work for achieving a better understanding of the impact of the above mentioned phenomena, and support improved risk management, better planning and preparedness, faster, adapted and efficient response, towards the sustainable reconstruction of historic areas. By addressing key actors, such as policy makers, cultural institutions, municipalities, public authorities, people in charge of the management and preservation of national and local tangible cultural heritage assets, as well as researchers, archaeologists and conservators, spread of results will be ensured. This magazine offers undoubtedly a great way to share our progress within the course of the project, and keep in touch. I would like to thank all of our colleagues in HYPERION consortium for contributing to this brand new issue, and wish you have a great time reading.

Enjoy!

Welcome message by HYPERION Project Manager, Dr. Antonis Kalis

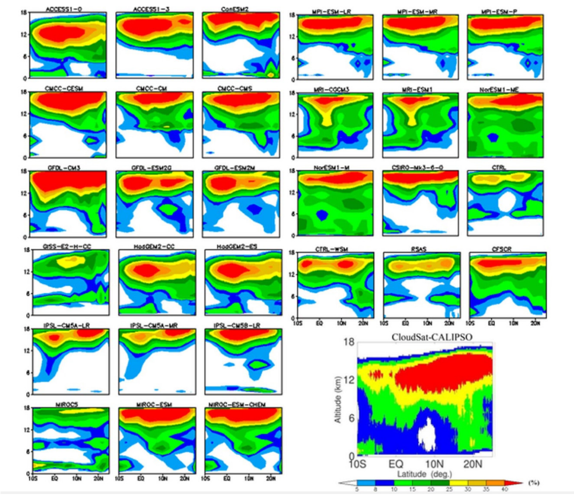
Dear readers,

Welcome! Through this magazine we proudly present to you a glimpse on the developments within HYPERION, a pivotal EU funded project which started in June 2019, and marks the strong recent concern of the European Commission on preserving cultural heritage in times of Climate Change (CC). This strong interest on past monuments is actually more of an apprehension on our present and future, since cultural heritage is a connecting bond of our communities. Within this context, HYPERION introduces innovative methodologies which will help assess the effect of a multitude of CC or human inflicted threats on the landmarks themselves; provides local authorities both with decision support tools to assess and mitigate the effects of unforeseen events, and with a training environment which will render them capable of dealing with new CC related threats; integrates community engagement tools that amplify community involvement both pro-actively and reactively to major disrupting events; develops business continuity plans to strengthen community responsiveness. In summary, HYPERION creates a strong safety net for supporting both the Cultural Heritage structures, and the surrounding communities. This is of utmost importance in an era of globalization and extreme climate change related events, helping in the development of communal bonds, now and in the future.

Happy reading!

HYPERION - Vision and Challenges

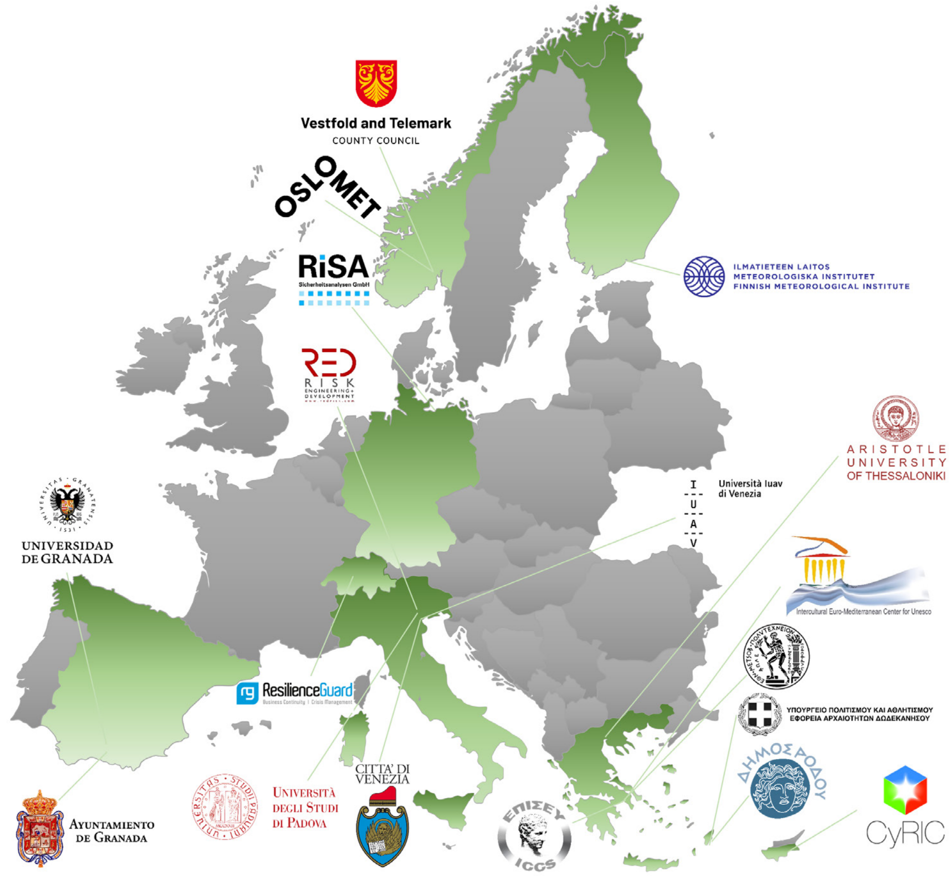
Recent studies highlight the potential impact of **Climate Change** and **geo-hazards** (such as landslides and earthquakes) on historic areas hosting **Cultural Heritage** sites and monuments, which in turn yield significant adverse impacts on economies, politics and societies. The deterioration of Cultural Heritage sites is one of the biggest challenges in conservation; aspects such as building technologies/materials, structural responses, preventive measures and restoration strategies, resilience and adaptation methodologies must be considered.



HYPERION will take into account the local **eco-systems** in the Cultural Heritage areas, mapping out their interactions and following a truly **integrated/sustainable reconstruction** approach (technical, social, institutional, environmental and economic level), by incorporating **active communities' participation** and by supporting new business models based on the concept of a **"load-balancing"** economy, and offering **financial risk-transfer tools** that can ensure the immediate funds availability to fuel timely build-back-better efforts.

HYPERION will leverage existing tools and services (e.g., climate/extreme events models, and their impacts, decay models of building materials, Copernicus services, etc.), novel technologies (terrestrial and satellite imaging for wide-area inspection, advanced machine learning, etc.) to deliver an **integrated resilience assessment platform**, addressing multi-hazard risk understanding, better preparedness, faster, adapted and efficient response, and **sustainable reconstruction** of historic areas.

Presentation of partners' responsibilities



Research/Academic Partners

Eight universities and research organisations from Greece, Finland, Norway, Italy and Spain are participating in the project:

- The **Institute of Communication and Computer Systems (ICCS, GR)** is the project coordinator, and responsible for the delivery of the module supporting social/communities' participation in the platform, as well as the smart tags and the networking issues.
- The **Finnish Meteorological Institute (FMI, FI)** is involved in the Climate & Hydrological Data Provider and Regional Downscaling.
- The **Oslo Metropolitan University- (OSLOMET, NO)** develops the HT tool, spearheads the development of the SG tool, undertakes the characterization and laboratory testing of wood and develops hydrothermal and structural models for CH building materials, with particular focus on timber structures, as well as any ancillary non-CH steel structures (in collaboration with UGR). OSLOMET participates with two research groups: The Sustainable Built Environment (SustainaBUILT) and the Structural Engineering Research Group (SERG). Both research groups belong to the Faculty of Technology, Art and Design (TKD).
- The **National Technical University of Athens (NTUA, GR)** is responsible for the enhanced CV and ML algorithms, plus the geotechnical, earthquake and structural engineering and vulnerability assessment of the structures and the development of fast damage assessment and mapping (satellite and UAV- based). Along with RG, NTUA will develop the resilience assessment framework and code it into the open-source HRAP engine. NTUA participates with two research groups; the School of Civil Engineering and the School of Rural and Surveying Engineering (Remote Sensing Lab).
- The **University of Padova – (UNIPD, IT)** will refine damage and dose-response functions for building materials, improving prediction on decline of physical-mechanical properties, especially under extreme events.
- The **University of Granada – (UGR, ES)** will undertake the detailed modelling of masonry and rammed-earth CH buildings, offer structural model updating software, develop surrogate models for rapid assessment of extreme event impacts on the CH sites, and develop sustainable building rehabilitation approaches.
- The **Aristotle University of Thessaloniki, (AUTH, GR)** is responsible for the Coupled Multi-nested Local Scale Modelling and Impact Mapping and the cost-benefit analysis for addressing the potential socio-economic aspects of the project.
- The **LAMA - Laboratory for Analysing Materials of Ancient origin of the IUAV University of Venice (IT)**- is responsible for the characterization of the building materials and identification of their deterioration patterns.

Industrial Partners

Four industrial partners participate in the project: Cyprus Research and Innovation Center Ltd (CyRIC, CY), Risk Engineering & Design (RED, IT), RisaSicherheitsanalysen Gmbh (RISA, DE), Resilience Guard Gmbh (RG, CH).
A brief description of their key responsibilities follows:

- **RISA** is responsible for the software integration and the provision of the final software of HRAP and DSS.

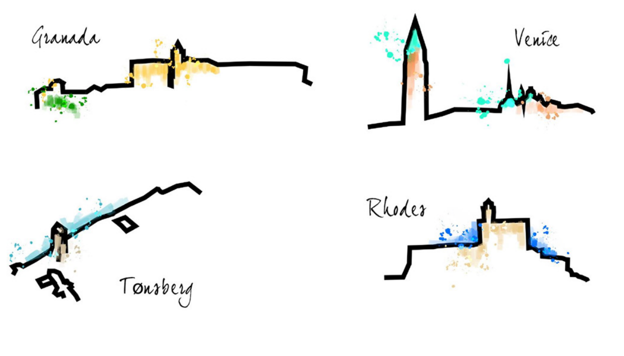
- **RG** is responsible for the local community business interruption impact analysis, business resilience and continuity strategies, training and awareness of critical audiences.

- **CYRIC** is responsible for the system integration activities.

- **RED** is involved in the seismic hazard assessment, the HRAP modelling of each CH-site and the development of financial mitigation tools.

Cultural Organizations

- **Intercultural Euro Mediterranean Center of UNESCO** (**IEMC, GR**) is responsible for the standardisation, dissemination and communication activities of the project.



By Chiara Coletti e Gloria Zaccariello

End - Users

Four European cities participate in the HYPERION program:

- The city of Tønsberg is represented by **Vestfold og Telemark fylkeskommune (VFK)**. The project results will be exploited: (1) to plan and realize climate-resilient technical solutions on Cultural Heritage-objects and sites within their jurisdiction, (2) to establish standards and "best practice" among conservators, artisans, manufacturers and suppliers within the field of conservation and restoration, (3) to calculate and establish possible future costs related to CC within the field towards national and regional authorities.

- The city of Venice is represented by **Comune di Venezia (CVI)**; CVI is exploiting the results to: (1) widen the planning and design of the due interventions to protect Venice's unique cultural heritage from the effects of CC, (2) spread project knowledge among the City's staff working in the field, (3) cooperate with local project partners and (4) boost further scientific developments and enlarge the methodology testing area.

- The city of Rhodes is represented by **Dimos Rodou** (Municipality of Rhodes) (DR) and the **Ephorate of Antiquities of the Dodecanese** (EFAD). The project results will be used to make better assessment of current state of CH sites in the municipality of Rhodes and in defining further restoration priorities.EFAD will use project results, including the knowledge acquired and the methodology developed, to improve and widen the planning and design of the due interventions.

- The municipality and the cultural authority of Granada are represented by **Ayuntamiento De Granada (ADG)**. ADG will designate the different CH and non-CH sites of the municipality for risk assessment, as well as provide census, structure and infrastructure data for the entire study area.

Concept

HYPERION will introduce a research framework towards re-scaling results for the potential atmospheric composition based on future CC scenarios, as well as associated risk maps down to at the very local scale, with a high end resolution of few meters by few meters. Applying atmospheric modelling for specific **Climate Change scenarios** at such refined spatial and time scales allows for an accurate quantitative and qualitative impact assessment of the estimated micro-climatic and atmospheric stressors.

HYPERION will perform combined **Hygro-Thermal** and **Structural/Geotechnical** analysis of the Cultural Heritage sites and damage assessment under normal (past) and changed (future) conditions (anthropogenic or/and natural disasters). The data coming from the deployed sensors will be coupled with simulated data over the wider Cultural Heritage area (under Holistic Risk Assessment Platform) and will be further analysed through our data management system and support **communities' participation** and **public awareness**. The data from the sensors will feed the **Decision Support System** to provide appropriate adaptation and mitigation strategies.

The **HYPERION** system incorporates an enhanced visualization tool with improved 4D capabilities (3D plus time) that can provide a simple and easy way for all relevant stakeholders to assess damage and risk. The produced vulnerability map will be used by the local authorities to assess the threats of climate change, visualize the built heritage and cultural landscape under future climate scenarios, model the effects of different adaptation strategies, and ultimately prioritize any rehabilitation actions to best allocate funds in both pre- and post-event environments.

HYPERION will include multiscale monitoring ranging from satellite to ground inspection. It will exploit the advantages of passive (multi-spectral, hyperspectral and thermal) and active (SAR) remote sensing data using optimal image processing and data integration methods based on time series analysis, photogrammetric analysis, SAR differential interferometry, and advanced ML, in order to perform routine inspection and damage assessment after disasters in the monuments as well as in the broader area.

HYPERION Components

Technologies

- Advanced Machine Learning
- Participative Cultural Heritage
- Time Series Interferometric Synthetic Aperture Radar (TSInSAR)
- High end numerical modeling

Services

- Euro-CORDEX
- Copernicus Climate Change (C3S)
- Copernicus Emergency Management (CEMS)
- Galileo

Tools

- Terrestrial Imaging
- Satellite Imaging
- Wide Area Inspection
- Decay models of materials
- Impact assessment of the prevailing meteorological and climatic conditions at a micro-scale level

Innovation Pillars

1

Material-specific dose-response equations for increasing dynamic Heat-Air-Moisture models' accuracy

HYPERION will fill the gap of inadequacy of dose-response deterioration equations and sparsity in considering site-specific environmental parameters influencing future climate conditions, by improving the knowledge on measurable parameters influencing degradation rate, and refining adequate material-specific recession models to be integrated in vulnerability simulations under high resolution site-optimised climate projections.

2

Modelling tools and simulators to be used for increasing the resilience of the historic areas

New multi-scale and multi-nesting approaches for the assessment of atmospheric forcing on soil and structures will be developed to help determine the soil temperature and moisture content for different scenarios.

The integration of monitoring data from advanced sensors besides traditional ones along with the expert knowledge of the partners will allow for improved system identification and consequently more accurate vulnerability assessment.

Modelling the dose-response function is crucial for understanding the behaviour of old materials that are not included in available databases.

The open-source/architecture of HRAP will enable an unprecedented increase in the number of available models, data, and network simulators to flow between end-users, engineers, catastrophe risk modellers, and stakeholders.

3

Situational Awareness: Earth Observation (EO), Computer Vision (CV), Machine Learning (ML)

HYPERION will integrate multi-temporal space-ground-airborne geospatial data and operational services towards monitoring hazard and exposure in near Real-Time at all geographical scales, providing evidence and supportingstrategies for decision-making.

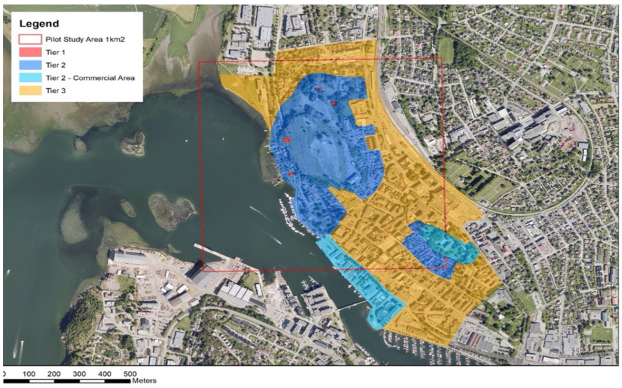
Impact

1. Multi-hazard risk understanding
2. Better preparedness
3. Faster, adapted, efficient response
4. Sustainable reconstruction
5. Quantitative impact assessment

HYPERION Test Sites

HYPERION will perform extensive tests in four demo sites, in Greece (Rhodes), Spain (Granada), Norway (Tønsberg) and Italy (Venice). The historic areas will be modelled at building level through reduced-order models based on archetype structures of each area. A number of selected structures (CH value) will be modelled and monitored in detail. The demonstration shall prove the suitability of the HYPERION platform for multiple hazard assessment and optimized operational and strategic decisions for management and maintenance of the historic areas, considering additional hazards of interest for CH and non-CH areas of the city.

Vestfold og Telemark fylkeskommune



Vestfold and Telemark county selected the buildings and constructions for the demonstration activities. Tiers 1,2,3 are represented with the different colours.

The town is dominated by a cliff with steep sides (Slottsfjellet), which contained the Castrum Tunsbergis. Urban structures of long, narrow estates divided by streets and narrow alleys were established in the 12th century at the foot of the cliff and along the harbour.

In the city of Tønsberg Tier 1 constructions are shown in detail.


The Heierstad Loft


Bentegarden

Comune di Venezia (CVI)

The proposed sites have been identified for their different location in the urbis form of the city in order to understand how the main building materials (stone and marble, brick, wood, metal, plaster) can be quantitatively and qualitatively subject to chemical variations.
The two CH selected buildings for the demonstration activities are:
1) **the Marciana area**, 2) **Ca' Pesaro Palace**. Both are exposed to different pollutants from various sources. St. Mark square is mostly affected by the emissions of small boats and touristic large ships and Ca' Pesaro is mainly exposed to the intense traffic of public and private transport along the Canal Grande and the pollution is acute.

The Marciana area, Torre dell' Orologio (The Clock Tower)

The Clock Tower , classified as Tier 1, is one of the most famous architectural landmarks in Venice, standing over an arch that leads from St. Mark's square into what is the main shopping street of the city, the old Merceria. The tower with its large Astronomical Clock was designed by Mauro Colussi in the early 16th century, it was built with brick, stone and wood and covered with stone material. The monument that stands in the Marciana area, faces the city's waterfront and it is therefore exposed to the sun, rain, high water, wind with all the saline humidity coming from the sea. In addition, the foundation of St. Mark square is lower than the rest of the city, and frequently subjected to the high water phenom non, which comes directly from the large San Marco basin by wave motion. The presence of erosive salty water is massive, almost constant, and salt affects the buildings' masonry. Its position makes it a perfect place where to position specific sensors to detect the polluting agents responsible for the deterioration of the building materials.

Ca' Pesaro Palace

The grandiose palace of Ca 'Pesaro, classified as Tier 2, now seat of the International Gallery of Modern Art, was built in the second half of the seventeenth century after a project by the Venetian baroque architect, Baldassarre Longhena. Overlooking the Grand Canal, the city's main waterway, the Palace was built using the traditional techniques and materials of the time and the two facades were coated with Istrian stone. The bridge connecting Venice's historical centre to the mainland allowing both car and train transportation, the buildings along the Grand Canal, from piazzale Roma to the Academia bridge, the Rialto bridge and the Mercerie, the Giudecca canal, the Civil Hospital; these buildings and infrastructures are fundamental for the city and Business Continuity. In consideration of climate change challenge (in the latest days the tide level raised at rates that are unprecedented), specific analysis of the effects of climate agents on building materials, and consequently on the techniques for their use, would help to understand which solutions are to be preferred for the restoration of the monuments and the buildings. The area to be classified in Tier 3 includes the areas with infrastructures and important sites that border the lagoon and therefore the city of Venice, like the airport, the port mouths, the industrial site of Porto Marghera. The dangers that can derive from these areas can have a serious impact on the city: if on the one hand the closure of the airport or of the port mouth can paralyse long-range transports, an accident occurring in the petrochemical industry area might block the city life for a very long time.

Ayuntamiento De Granada (ADG)

In Granada there are around 2,000 monumental buildings with various preservation-related problems. In Granada we can see what could be one of the first domes in the history of construction (Palace of the Lions, Alhambra).
The mill of the Marquis of Rivas is classified as Tier 1. The main characteristic of this CH building is the rammed earth construction with bricks from the XI century.

The mill of the Marquis of Rivas and a close up from the Rammed earth construction (locally named as "tapial").

San Jerónimo Monastery and the fire house of Granada, located at the Almanjayar area, are considered as the non-CH building. Both buildings are defined as Tier 2. Finally the Sabika hill in Alhambra is also defined as Tier 2.

Dimos Rodou (DR)

The ancient city of Rhodes was founded in 408 BC. In the early 12th century, a new wall enclosed a rectangular area of 17.5 hectares. This town was conquered by the order of St John of Jerusalem (1309-1523). The medieval city of Rhodes (UNESCO world CH site) maintains the architectural character and the urban organization of a medieval city as well as its primary building materials: stone, wood and iron.

Saint Nikolas lighthouse and the fort of Naillac

In Rhodes, Saint Nikolas, the fort of Naillac, the Roman bridge and Rodini are classified as Tier 1. The fortress of Saint Nikolas is a single stronghold that occupies the northern tip of the homonymous pier. It includes consecutive reinforcements and expansions after the destructions it suffered from sieges, during which it acted as "a key to the defense of the city". It was built by the duke Philip of Burgundy between 1464-67. The Naillac pier and rampart were constructed around 1400 on the Hellenistic pier and they were part of the fortification of the "Great Port", the Commercial Harbour of Rhodes.

The Roman Bridge is a monument of particular archaeological importance, since it is one of the few ancient bridges surviving in Greece, being furthermore in use until today. At Rhodini five "structures" are included in the program:
1. "Tomb of the Ptolemies". 2. Grave enclosure with shields and "Korinthian Tomb". 3. Sanctuary with vaulted-roofed chambers. 4. Grave enclosure. 5. Grotto sanctuary.
The monumental graves preserved in Rhodini are dated in the Hellenistic period, in the 3rd- 2nd century BC. They are concentrated in the southern part of the Archaeological site, around the so called "Tomb of the Ptolemies".

Operational and CH buildings, that are important for the Business Continuity and financial sustainability of the study area, such as the Fire station, the Police station, the S. Aegean Regional building, the City Hall and the Central offices of Ephorate of the Dodecanese islands, are included in Tier 2. Also, the buildings of Electrical power substation, Military Headquarters, Public services building, Regional Hospital are included as Tier 2. The overall area that will be modelled/studied will be the whole city of Rhodes, an area of approximately 1400 Km^2.

The tomb of the Ptolemies

The Korinthian Tomb at Rhodini

HYPERION's Achievements Towards Excellence (2019-2020)

Atmospheric Forcing Modelling, Weather Now/ Fore-Casting and Data Processing.

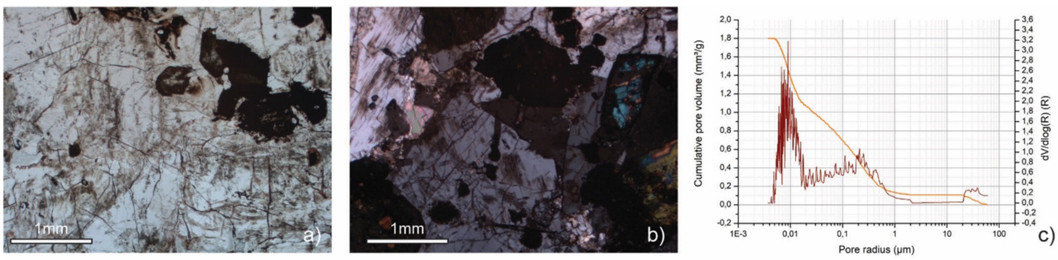
Collection of data (HYPERION Geographic Data and Services inventorying and Open Data repositories gathering). Considering the general scope as well as the specific requirements of the project, specifications for five domains of interest needed to be defined. Since each one comprised a dataset category for which meticulous data gathering was critical, a table that summarized all the required information was generated. The categories for which data information was presented in this context were: Geometry, Land Use, Vegetation, Hydrology and Satellite.

Assessment of Climate Data and Selection of Scenarios: Specific severity criteria for climate and atmospheric stressors were developed and an analysis on existing EURO-CORDEX climate simulation results to identify relevant "episodic" periods were made.
Interfacing and processing of high-resolution land use maps and maps of surface parameters: The main purpose was to record all data sources and data services that will be needed during the next phases. This included the already available files, as well as the ones that were to be collected within the given timeline. The Task served for a) the reliable quantification of climatic, hydrological and atmospheric stressors, b) the creation of the Land Surface model that will be used to account for the impact of present and future climate parameters on soil surface, c) the provision of input for the relevant regulatory framework that is under revision, d) multi-hazard modelling, extended to cover CC related hazards as well as geo-hazards, e) the on-site integration, demonstration and validation of the HYPERION platform.

Characterisation of the Building Materials and Identification of the Deterioration Patterns.

The purpose is to provide the mineralogical-petrographic characterization and classification of the building materials, refine the dose-response functions, identify the physical decay and chemical weathering processes occurred on the building materials, map deterioration micro- and macro-morphologies, and evaluate the physical-mechanical behaviour of the materials. These data will feed an HT simulator for accurate predictive assessment of old building materials under risk scenarios.

During the 1st year of the HYPERION project, the researchers were engaged in the selection, supply, and characterisation of specific rock types, characteristic of the demonstration sites of Granada, Rhodes, Tønsberg and Venice. These materials will be tested under artificial and natural decay conditions. The lithologies were carefully selected to represent the widest variability of rock behaviour under different weathering factors. The first tranche of rock samples, including seven lithologies from Italy and two from Norway, was petrographically analysed under optical microscopy, while, macroscopic facies, porosity and physical-mechanical features were studied by spectrophotometry, mercury intrusion porosimetry, and ultrasonic (NDT) non-destructive testing, respectively. Figure 1 shows examples of data and images for the syenite from Tønsberg.

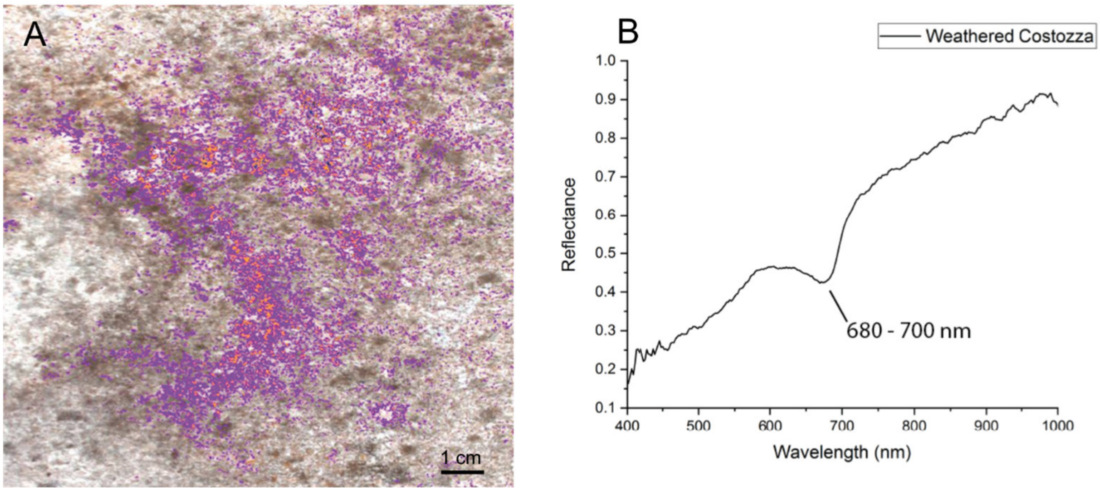


Tønsberg syenite. Optical microscopy photomicrographs taken in plane-polarized (a) and crossed-polarized (b) light conditions. Exemplary pore size distribution obtained by mercury intrusion porosimetry (c).

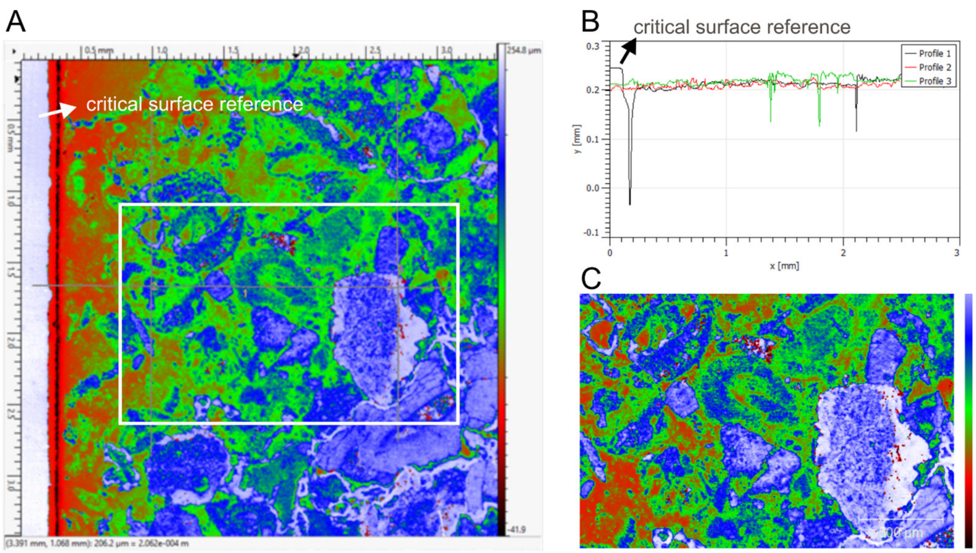
In the context of the HYPERION project, the chemical alteration and physical deterioration of construction stone materials will be evaluated on individual CH monuments, and vulnerability under specific climate forcing will be assessed through laboratory experiments, providing information on damage, decay, and emerging hazards. Part of this work has been conducted already through hyper-spectral analyses in the VIS-SWIR range. As an example, laboratory analyses showed that with hyper-spectral analyses bio-deterioration could be easily tracked on weathered rocks. In the following figure, a map of chlorophyll absorption band (at 680-700 nm) on a weathered stone (the Italian Costozza Limestone) is shown. The same will be done on the CH buildings and monuments, providing a non-destructive and efficient way to map the deterioration patterns.

This is the first time that hyper-spectral analyses are used to asses building materials decay. For this reason we are investigating other features indicative of degradation on building stones, like the pore-filling effect of salts and mineral replacement by secondary alteration phases.

Stone decay and the related surface texture changes were also examined in areas up to 5 mm using a 3D non-contact optical profilometer. Surface regression and roughness parameters (ISO 25178) were measured before and after climate chamber tests with respect to a critical surface reference. Profiles measurements were performed by specifying points on the 3D observation image.

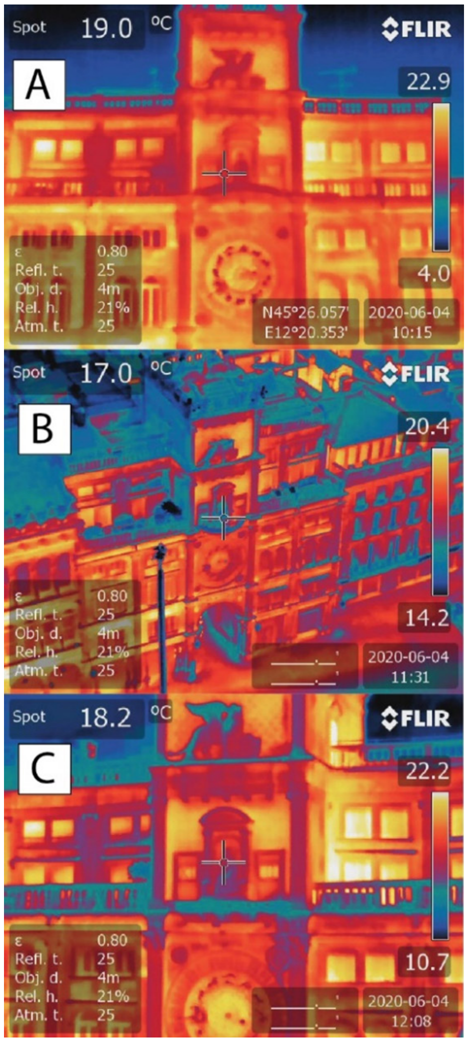


On the left: spectral map on the Italian Costozza Limestone of the 680-700 nm absorption band related to chlorophyll. The band depth is shallow in the purple areas, increases in the orange areas and reaches the maximum in the dark blue spots. On the right: an example of the Costozza Limestone spectra in the VIS range where bio-deterioration with chlorophyll absorption (680-700 nm) is found.



3D surface texture analysis after rainwater cycles. Area of analysis 3.5x3.5 mm. Scanning resolution of 2 μm. A) Total area analysed: the critical surface reference (on the left) and the profiles lines 1, 2 and 3. B) Profiles 1, 2 and 3 (Fig. A); C); Detail of Fig. A

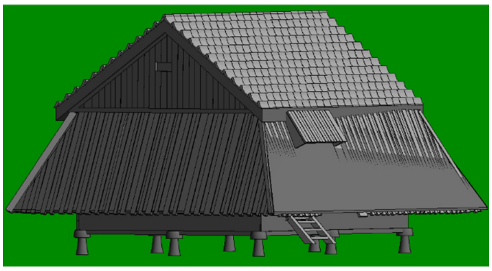
Surveys at the Clock Tower in Venice (Tier 1 - Building) have been done to perform the 3D photogrammetry and to plan the on-site analyses. In the following figures A, B and C three different preliminary thermal images from different point of views are shown. The different acquisition points were needed to allow the 3D image reconstruction and to obtain both detailed spectral images close to the Clock Tower and broad images to have an idea of the overall site composition and degradation.



Above: The Clock Tower, Tier 1 – Building in Venice. On the right: Thermal images of the Clock Tower (Venice) taken during the preliminary survey. A) Image taken in front of the Tower in the San Marco Square. This position gives a detailed spectral map. B) Image taken from the Correr Museum. From this position, it was possible to have an overview of the entire site. C) Image acquired from the Basilica di San Marco (St Mark's Basilica). This provides a detailed spectral map of the building from a different viewpoint.

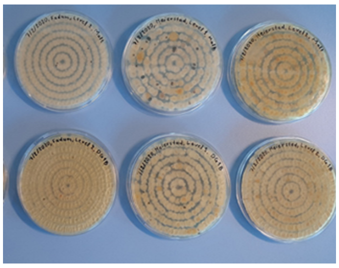
Hygrothermal simulator

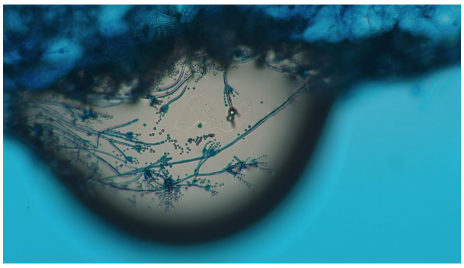
The deterioration of the building materials in the cultural heritage sites is strongly connected to their coupled hygrothermal performance, which is further linked to the ambient weather conditions, climate characteristics and thermophysical and hygric material properties. During the first year of HYPERION, the focus of this significant task has been put on the CH site of Tønsberg, Norway. In particular, the hygrothermal performance of two timber historic buildings, i.e. Fadum Storehouse and Heierstad Loft, have been continuously monitored, while the biodeterioration risk under various climate change scenarios has been investigated.
In the framework of research, both measurements and numerical simulations have been employed. Since November 2019, when the measurements started, the exterior microclimatic conditions and the indoor environment as well as the temperature and moisture content in timber have been continuously monitored and logged. The set of the numerical simulations consists of i) hygrothermal models, used for the estimation of the temperature and moisture content in the building components and ii) a mathematical model of mould growth on wooden material (VTT mould model), used to assess the mould risk on various cross sections of the buildings on the basis of the temperature and moisture content results. The hygrothermal models have been validated through the measurements, while the results of mould growth risk have been verified by the in-situ inspection and microbiological analysis in the laboratory. Comparing the mould risk of the past years to the future ones, an increasing trend can be observed.



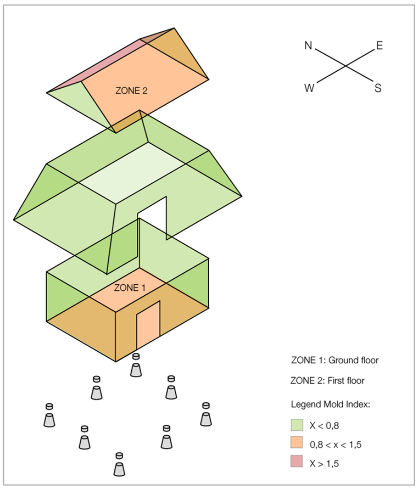
The Fadum storehouse and the 3D model used in the numerical simulations

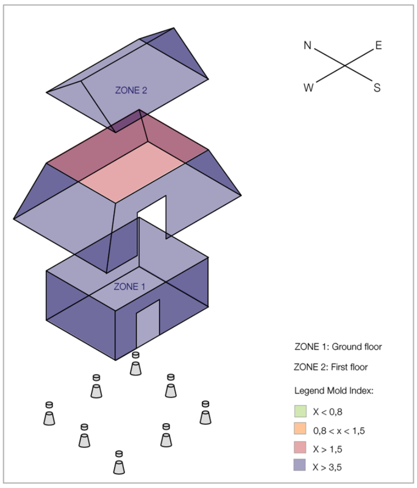
Measured and simulated values of moisture content in the exterior log walls on the ground and first floor at the Fadum storehouse.



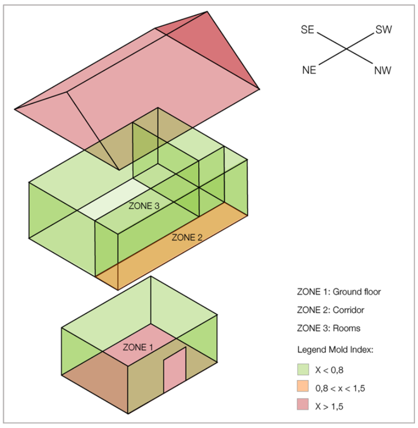


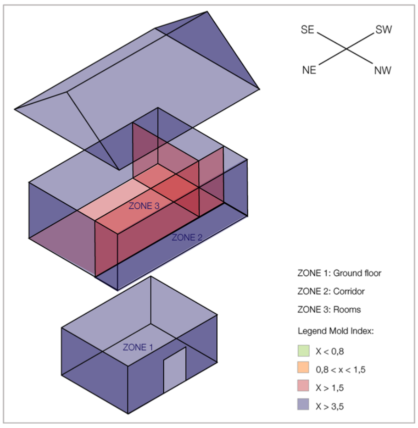
Identification of microfungi in the laboratory (left). Penicillium Glabrum has been identified as one of the dominant fungi spices found in the Fadum storehouse (right)





Computation of mould index in building elements in the Fadum Storehouse, under current climate (left) and expected climate in 2100 (RCP 8.5 scenario)





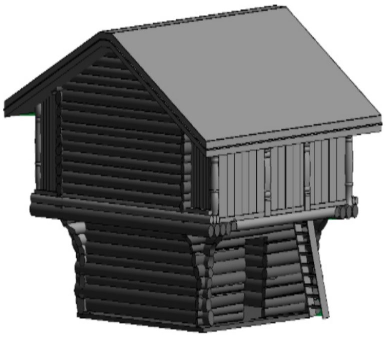
Computation of mould index in building elements in the Heierstad Loft, under current climate (left) and expected climate in 2100 (RCP 8.5 scenario)

Multi-Hazards Modelling, Vulnerability and Impact Assessment of the historic areas

For the structural vulnerability assessment of cultural heritage sites and in the context of HYPERION project, a preliminary structural survey has been done for the site in Tønsberg and the specific case studies. In order to have a robust 3D geometrical documentation, as well as damage detection of the timber elements and coatings, two heritage timber log-houses have been chosen for 3D laser scanning.

A simplified model for numerical modelling of masonry structures has been proposed and verified. Through this method, the structure will be modeled by beams and columns and nonlinear shear behavior springs in the middle of the elements. This model will be utilized in the structural geotechnical simulator.

3D laser scanning has been done on Slottsfjell tower in Tønsberg. The 3D geometry from the 3D laser scan has been converted to a finite element model in DIANA FEA software. Furthermore, accelerometers have been installed on the tower in order to investigate the dynamic characteristics of the structure. Then the finite element model has been updated by the results from the ambient vibration testing resulting in a robust model for further analysis.



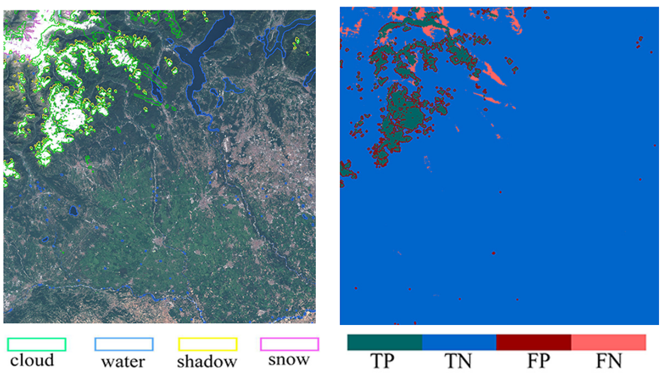
Heierstad Loft and the 3D model of the case study

3D documentation of Slottsfjell tower and the finite element model

The Remote Sensing-based multiscale monitoring system (RS-MMS)

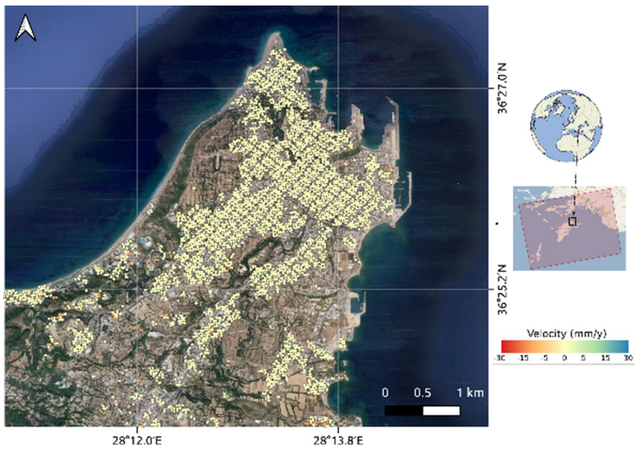
In the context of the HYPERION project, the Remote Sensing-based multiscale monitoring system (RS-MMS) will be created aiming at providing detection of damage/degradation and emerging hazards as well as rapid post-hazard event damage assessment of both the individual CH monuments and the broader area of the pilot areas. RS-MMS integrates data from various remote sensing platforms such as satellites, UAVs and ground control stations, with the focus on the optimal processing of remote sensing data in order to match the specific monitoring needs for historic monuments or areas and hazard scenarios. Remote Sensing products enable the inspection of CH assets for hazards with slow or gradual onset. In particular, they include three-dimensional models, ground deformation, land cover change detection and hyperspectral image maps.

In the first year of HYPERION project, a processing scheme for ground deformation monitoring based on satellite SAR (Synthetic Aperture Radar) data over broader CH regions was implemented. The solution is based on well-established time series techniques available in several open source software packages.
Furthermore, the pre-processing chain for satellite high resolution optical images has been established and an effective Neural Network-based method for cloud removal has been developed (Kristollari & Karathanassi, 2020). The results of this method are presented in the following images (Sentinel-2 multispectral image).



T: True, F: False, P: Positive, N: Negative

A performance analysis of the available open source methods (Karamvasis & Karathanassi, 2020) was performed in order to determine the most suitable approach for the pilot cases. The Small baseline InSAR time series approach has been selected (Yunjun et al., 2019) and a methodology has been developed and applied on Rhodes pilot area, which consists of standardized and ad-hoc processing steps. The ground velocity results over a broader region of Rhodes pilot case are presented in the following image.



Ground velocity

A thorough bibliography study has been accomplished and the land cover change detection methodology has been selected. The methodology will investigate two approaches that make use of convolutional neural networks.

The first one is Early Fusion (EF), which consists of concatenating the two multi-temporal image pairs as the first step of the network. The second one is Siamese networks, where each of the patches are processed in parallel by two branches of convolutional layers, usually with shared weights.

Training data will be manually extracted by the multi-temporal images and simple processing techniques such as band subtraction ratio and spectral vector angle will give a preliminary indication of the changes. If necessary, data augmentation techniques will be explored along with publicly available databases.

Publications

Publications in scientific journals with topics relevant to the research and innovation work target the scientific communities directly or indirectly at the scope of HYPERION. These activities reinforce the project awareness, allow HYPERION concepts and solutions to leverage other research projects, foster cross-project cooperation and provide fundamental means of peer reviewing of the scientific approaches of HYPERION. The following articles have been published:

NTUA, School of Rural and Surveying Engineering

"Performance analysis of open source time series InSAR methods for deformation monitoring over a broader mining region"
Karathanassi Vassilia and Kleanthis Karamvasis, Remote Sensing Journal 12(9), 1380, 2020.Pub Date: 2020-04-27, https://doi.org/10.3390/rs12091380

Abstract
Time Series Interferometric Synthetic Aperture Radar (TSInSAR) methods have been widely and successfully applied for spatiotemporal ground deformation monitoring. The main groups of methodological approaches are often referred to as Persistent Scatterer (PS), Small Baseline (SB), and hybrid approaches that incorporate PS and SB concepts. While TSInSAR techniques have long been able to provide accurate deformation rates for various applications, their corresponding performance in complex environments such as mining areas has to be investigated. This study focuses on comparing the performance of three open source TSInSAR toolboxes (Stamps, Giant, Mintpy) over an extended region that includes an active opencast coal mine. We present the deformation results of each TSInSAR method on a Sentinel-1 dataset of 125 acquisitions spanning around 2.5 years over the Ptolemaida-Florina coal mine site that is characterized by several environmental and surface deformation conditions. First, a cross-comparison analysis is presented over different land cover classes. The study shows that all TSInSAR methods are capable for generating similar ground deformation results when the area has stable ground scattering conditions and the dataset sufficient temporal sampling. The most controversial results between TSInSAR approaches were found in land cover classes that include medium to high vegetation. An external comparative analysis between the different results from TSInSAR methods and levelling measurements is also performed. Stamps approach presented the best agreement with the in-situ deformation rates. The Giant approach yielded the best cumulative deformation results due to our a priori knowledge of temporal behavior of deformation in the vicinity of the levelling locations. Finally, we discuss the main pros and cons of each TSInSAR approach and we highlight the importance of comparison analysis that can provide insights and can lead to better interpretation of the results.

NTUA, School of Rural and Surveying Engineering

"Fine-tuning Self-Organizing Maps for Sentinel-2 imagery: Separating Clouds from Bright Surfaces"
Viktoria Kristollari and Vassilia Karathanassi, Remote Sens. 12(12), 1923, 2020; Pub date: 2020-6-14, https://doi.org/10.3390/rs12121923

Abstract
Removal of cloud interference is a crucial step for the exploitation of the spectral information stored in optical satellite images. Several cloud masking approaches have been developed through time, based on direct interpretation of the spectral and temporal properties of clouds through thresholds. The problem has also been tackled by machine learning methods with artificial neural networks being among the most recent ones. Detection of bright non-cloud objects consists one of the most difficult cases in cloud masking applications since spectral information alone often proves inadequate for their separation from clouds. Scientific attention has recently been redrawn on self-organizing maps (SOMs) because of their unique ability to preserve topologic relations, added to the advantage of faster training time and more interpretative behavior compared to other types of artificial neural networks (e.g. convolutional). This study proposed a fine-tuned SOM for the separation of clouds from bright land areas, by directly locating the neurons that corresponded to misclassified pixels. Then, the incorrect labels of the neurons were altered without applying further training. The network was trained on the largest publicly available spectral database for Sentinel-2 cloud masking applications and was tested on an independent database of Sentinel-2 cloud masks.

Conferences

During the first year of its implementation HYPERION project has been disseminated via the participation of consortium partners to the following events (conferences):

HYPERION in the International Conference on Seismology and Earthquake Engineering (SEE) in Tehran, Iran, 11-13 Nov 2019. www.see8.ir

Prof. D. Vamvatsikos presented the paper: "Decision support, resilience and sustainable reconstruction of historical city cores under seismic threat: The HYPERION approach" http://www.iiees.ac.ir/fa/see8pub/ (p.546).

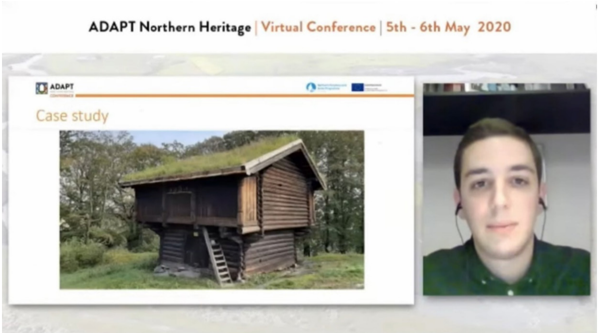
The International Conference on Seismology and Earthquake Engineering, was organized in Iran, with the theme of "Science-based Sustainable development in Earthquake prone countries". This was the eighth conference that provided a unique opportunity for Academia, professionals, experts, local governments, private sector and social science practitioners to exchange and share the latest advances in earthquake risk management, building and geotechnical Science, and policy initiatives that improve resiliency. The conference is organised every 4 years.

HYPERION in Adapt Northern Heritage Conference, May 5-6, 2020.

"HYPERION's decision support system for improved resilience and sustainable reconstruction of historic areas" was presented by Dr. Antonis Kalis, Project Manager, ICCS in Session 9/Topic: Urban Assessment.
Moreover, Petros Choidis, OSLOMET, presented the research conducted at OSLOMET in the context of HYPERION regarding the "Hygrothermal performance of an old building with log walls from the region of Vestfold in Norway", in Session 4/Topic: Buildings Retrofit and Fabric Assessments.
The conference explored impacts of climate change on historic places and how adaptation measures can help protect these places or manage their loss. Special themes of the conference were the cultural heritage in Arctic regions and of northern indigenous communities. The conference offered fruitful themed sessions, with blindly peer-reviewed, scholarly papers given by expert speakers involved in cultural heritage management in both research and practice. In view of the growing coronavirus outbreak in Europe, this virtual conference replaced the real-world conference, which was about to be held on the same dates in Edinburgh, Scotland.

HYPERION Presentations and Activities

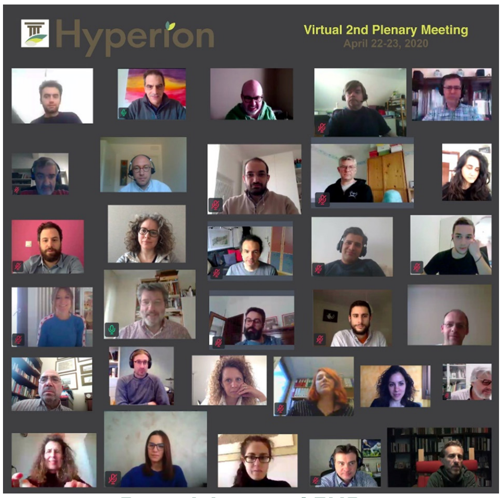
Dr. Antonis Kalis, et al., ICCS
"HYPERION's decision support system for improved resilience and sustainable reconstruction of historic areas" Session 9/Topic: Urban Assessment.



Petros Choidis, and D. Kraniotis, OSLOMET
"Hygrothermal performance of an old building with log walls from the region of Vestfold in Norway", Session 4/ Topic: Buildings Retrofit and Fabric Assessments.

HYPERION Plenary Meeting 1, held at the Katalima Glossas Ispanias, Rhodes, Greece, on the 23rd-24th October 2019. The overview of the Workpages, Deliverables/Milestones, Challenges/Problems, Detailed plan for the upcoming 6 months including timeplan and the KPIs were discussed.

Kick off meeting, Athens, 4 June 2019.



Granada's virtual PM2

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