EGU2020

NH6.4 abstracts

EGU2020-6652
https://doi.org/10.5194/egusphere-egu2020-6652
EGU General Assembly 2020

DInSAR analysis for geohazard assessment at the Roman city of Carsulae (Central Italy)

Gabriele Leoni[1], Silvia Casciarri[2], Paolo Maria Guarino[1], Luca Guerrieri[1], Francesco Menniti[1], Fabio Pagano[3], Irene Rischia[1], and Daniele Spizzichino[1]

[1]ISPRA, Geological Survey of Italy Dept. Via V. Brancati, 60; 00144, Roma.
[2]MIBACT, Polo Museale dell'Umbria. Corso Vannucci, 19; 06123, Perugia.
[3]MIBACT, Parco Archeologico dei Campi Flegrei. Rione Terra, Palazzo De Fraja; 80078, Pozzuoli.

The Roman city of Carsulae was founded in a strategic position along the Via Flaminia and it reached the maximum expansion during Roman Empire age, as attested by the presence of important monuments: *Forum*, *Basilica*, temples, theater, amphitheater, *Thermae*, arches. The settlement is located on a travertine plateau that overlay recent marine clay, both Lower Pleistocene aged, at the foothill of Monti Martani Mesozoic carbonatic range. The site is characterized by karst morphologies due to the dissolution of travertine because of the large amount of groundwater. Historical sources attributed the progressive decline and abandoning of Carsulae, during the 4th century AD, to the construction of a new branch of the Via Flaminia as well as to karst phenomena and to earthquakes.

A DInSAR analysis has been conducted in the Carsulae Archaeological Park using free input SAR data from Sentinel-1 to run the SBAS technique. This good combination of wavelength band, data resolution and revisit time optimizes the results in rural areas. To obtain meaningful data particular attention was paid to the selection of the Ground Reference Area as a geologically stable site. The resulting map of ground displacements during the period August 2018 – July 2019, analyzing both Ascendent and Descendent datasets, highlights a general small movement downward and westward, by 5-10 mm during the fall period (November 2018 – January 2019), followed by a substantially stable period until the end of the analysis. A field survey has been carried out on the archaeological remains to validate EO analysis, highlighting the absence of important damages, according with the overall ground stability of the site. Although some useful results were obtained, it is worth noting that the lack of coherence due to the rare natural or manmade reflectors and the availability of images limited to last year did not allow the complete exploitation of the technique.

The availability from Copernicus Programme of open data, frequently acquired and of good resolution allows EO monitoring to support traditional in situ monitoring (topographic surveys, inclinometer, extensometer, crack gauge, etc.). SBAS technique applied on Sentinel-1 data allows the detection of millimetric vertical ground displacements every 2 weeks, by a spatial resolution of about 10 meters. Moreover, this remote sensing survey covers at a same time a wide area without

the installation and the maintenance on the walls of reflecting devices that could limit the function or the fruition of monuments. Finally, the automation of DInSAR analysis enables the site managers to monitor natural threats through an efficient and sustainable system, selecting proper alert and mitigation measures when critical displacements are reached.

EGU2020-6857
https://doi.org/10.5194/egusphere-egu2020-6857
EGU General Assembly 2020

Characterization and monitoring of a riverbank failure in a UNESCO World Heritage Site: the 2016 Florence (Italy) case study

Veronica Tofani, Stefano Morelli, Veronica Pazzi, Luca Tanteri, Massimiliano Nocentini, Luca Lombardi, Giovanni Gigli, and Nicola Casagli
University of Florence, Earth Sciences Department, Firenze, Italy (veronica.tofani@unifi.it)

The impact of geo-hydrological hazards on cultural heritages represents a multi-disciplinary theme, which requires several different approaches. A complete analysis involves geotechnical, structural, and engineering issues and can lead to design adequate countermeasures. The Florence city historic centre, a UNESCO World Heritage Site since 1982, is crossed by the Arno River. The current riverbank morphology is the result of urbanization typical of centuries-old cities, which have mainly developed along the rivers to exploit the waterpower. In particular, the structure of the masonry riverbank is the product of a specific urban redevelopment approved in 1866 and completed in 1872 in the overall framework of the reorganization works carried out to let Florence be the capital of Italy. The vertical stone masonry retaining wall is anchored directly to the substrate of the riverbed with four rows of piles and the filling material is mainly compacted landfill. Buried subservices between the stone wall and the original riverbank and an arched vault culvert just adjacent to the buildings' foundations are also present. On May 25th, 2016, just few metres from the famous "Ponte Vecchio" bridge a portion of the of Lungarno Torrigiani road surface collapsed and the artificial riverbank was partially damaged by a cusp-shaped deformation without any shattering or toppling. The failure was approximately 4 m in height and 150 m in breadth (volume of about 1180 m3) via partial sliding of the underlying terrigenous layers towards the riverbed.

To identify the condition of damage of the involved structures, to define the causes of the failure, and to mitigate and preserve the cultural heritage site, a detailed analysis of this event was performed based on the integration of boreholes and geotechnical laboratory tests, remote-sensing techniques (i.e., terrestrial laser scanning), geophysical surveys (electrical resistivity topographies, downhole, and single-station seismic noise measurement), and stability analyses. The data obtained from these techniques were used to perform the limit equilibrium stability analysis of the slopes. Given the need to make the monitoring system immediately operational, remote instruments able to measure deformations from a station in the opposite bank were installed first. To monitor the crack pattern of the masonry embankment wall, also digital photogrammetry was employed together with the above-mentioned techniques.

The results show that both the aerial and submerged parts of the wall were deformed by the riverbank collapse without collapsing. Moreover, data allow to assess that the evolution of the

studied failure is the result of the combination and interaction of two different dynamics. The first one is the riverbank failure, a typical destructive phenomenon during extreme hydraulic conditions, well known throughout the history of city, especially after the intense urbanization starting from 1175. The second factor is the continuous loss of water from the subterranean pipes of the aqueduct, which is a more recent phenomenon that developed from the capillary diffusion of the modern structure in every part of the city. Thus, the major cause of the collapse can be attributed to the loss of water from the local subterranean pipes.

EGU2020-9519
https://doi.org/10.5194/egusphere-egu2020-9519
EGU General Assembly 2020

UAV photogrammetry and 3D scan data for topographic mapping and monitoring of maritime heritage

James Barry, Kieran Craven, Ronan O'Toole, and Sean Cullen
Geological Survey Ireland, Marine and Coastal Unit, Ireland (james.barry@gsi.ie)

Cultural heritage in maritime areas experience changes via natural and anthropogenic processes. This change must be monitored on a range of temporal and spatial scales to understand the evolution of these environments, particularly in the context of projected climate change yielding increased sea-levels and storm frequency. Commercial survey grade unmanned aerial vehicle (UAV) and 3D scan equipment, data processing and analysis tools are available to coastal and heritage managers, engineers and researchers.

This study, undertaken as part of the CHERISH project, analyses the use of photogrammetry via UAVs and 3D scan data from scanning total stations in Irish coastal locations with tangible cultural heritage to produce orthoimage mosaics and digital surface models. These products extend and complement acoustic bathymetric data in mapping vulnerable coastal regions. Results indicate that combining relevant techniques to produce seamless onshore-offshore maps can provide high-resolution information about emergent and submergent coastal geomorphology on a range of scales for use in monitoring and managing coastal heritage sites.

EGU2020-10701
https://doi.org/10.5194/egusphere-egu2020-10701
EGU General Assembly 2020

Towards a neural network approach for automated recognition of lichen-covered prehistoric carvings at Stonehenge

Gavin Leong and Matthew Brolly
University of Brighton, School of Environment and Technology, United Kingdom of Great Britain and Northern Ireland
(g.leong@brighton.ac.uk)

Petroglyphs (rock carvings) are a form of tangible cultural heritage that have been used to investigate cultural change and understand the origins of art and belief. However, many sites with rock carvings are accompanied by lichen. They often obscure these panels of rock art, rendering the cultural artefacts inaccessible to study, documentation and public enjoyment. Above all, lichen-covered rock carving is under the threat of lichen-attributed physical and chemical erosion. But evidence of a simultaneous protective role played by lichen has prompted concern that the removal of lichen may result in more rapid deterioration of the rock art.

Stonehenge, a UNESCO World Heritage site, provides a strong case study as dense lichen covers roughly a quarter of its above-ground stone surfaces, rendering it inaccessible to examination. 72 Early Bronze Age carvings have recently been found on the bare stone surfaces prompting concerns that lichen may be obscuring prehistoric rock art.

As a first step towards creating a technique for revealing carvings beneath lichen, an interdisciplinary approach was implemented. Photogrammetry-derived 3-D modelling and machine learning code written in Python were combined to create a method for identifying repeating carving motifs on bare stone surfaces. This code, a neural network classifier called MeshNet, “learns” 3-D shape representation from mesh-based 3-D models and was adapted to capture features of the rock carvings. After training on 150 models (75 carving and non-carving areas of the rock surface each) and testing on 38 models (19 carvings and non-carvings each), our method achieved 84.2% accuracy.

In previous work, we have shown that it is possible to recover indications of carvings covered by digitally simulated lichen. Thus, it will be possible to repeat our method on the same carvings with coverage of simulated lichen to compare accuracies. If successful, it will be the first demonstration of a technique capable of revealing carvings obscured by lichen using only a surface imaging technique.

Our current methodology for identifying rock carvings can be adopted by conservators and rock art site managers. It serves as a tool for non-rock art specialists to discover and digitally record repeating rock carving motifs. With further development using simulated lichen, it will partially alleviate the need to remove lichen from panels of rock carvings.

As our method is scale invariant, it could also be adapted for use in airborne and UAV platforms for discovering e.g. repeating natural landforms hidden by forest cover and buried Roman roads in 3-D terrain maps.

EGU2020-10914
https://doi.org/10.5194/egusphere-egu2020-10914
EGU General Assembly 2020

Integrated application of Remote sensing and Cultural heritage : the EO4GEO project scenarios

Daniele Spizzichino, Carlo Cipolloni, Valerio Comerci, Mariapia Congi, Claudia Delfini, Federica Ferrigno, Gabriele Leoni, Renato Ventura, and Luca Guerrieri
ISPRA, Roma, Italy (daniele.spizzichino@isprambiente.it)

EO4GEO is an Erasmus+ Project aiming at applying innovative solutions for education and training actions. EO4GEO will define a long-term and sustainable strategy to fill the gap between supply of and demand for space/geospatial education and training. The general project strategy will be implemented by: creating and maintaining an ontology-based Body of Knowledge for the space/geospatial sector; developing and integrating a dynamic collaborative platform; designing and developing a series of curricula and a rich portfolio of training modules directly usable in the context of Copernicus and other relevant EO programs; conducting a series of training actions, to test and validate the approach, for selected scenarios in three sub-sectors: 1) Integrated Applications, 2) Smart Cities, 3) Climate Change. ISPRA will contribute to the sub-sector Integrated Applications through the implementation of four case studies selected considering geo-hazard risk scenarios affecting different categories of exposed elements: i) landslide on linear infrastructure and transportation network (Petacciato village, CB); ii) instability events affecting Cultural Heritage, (Baia Archaeological Park, NA); iii) subsidence in urban area (Como city), iv) co-seismic ground deformation (Mt. Etna). The geo-hazard risk scenarios have been selected considering data availability and stakeholders interest; geo-hazard experts and final users (both public and private) will be involved during the scenario's implementation. Here we present the preliminary results concerning one of the listed case studies, slope instability affecting Cultural Heritage site: the Baia Archaeological Park (Naples). This area is located close by the Phlegrean Fields caldera, representing a unique example of volcanic-related subsidence with unrest cycles characterized by intense ground uplift and down lift; it extends exactly along the inner side of the western sector of the volcanic building of Baia. The particular location of the site, along the steep internal slopes of the volcano, required a strong control over the area development with massive terracing works. The instability phenomena seem to be related to the very high acclivity values of top sector of the slope favoring the activation of modest collapse phenomena as well as by ordinary management and maintenance of the area (e.g. invasive vegetation, absence of drainage systems). Preliminary InSAR analysis were performed exploiting ERS and COSMO Sky-Med datasets; the fist dataset show ground lowering phenomena, highlighting that subsidence affected areas close Phlegrean Fields during that period (1993 – 2003). The deformation rates (5-10 mm/yr) recorded in the investigated time interval are consistent with the general down lift cycle, while time series show some small uplift events. Forthcoming InSAR data processing will take into consideration the most recent SENTINEL-1 data, allowing us to assess the instability phenomena evolution of the area in a recent

time interval. In the general scope of the EO4GEO project ISPRA will develop all the case studies fostering the uptake of EO data, services and standardized methodologies of analysis. Available EO data provided from different satellite missions, both European and international (e.g. Sentinel from Copernicus program, COSMO-Sky-Med from ASI), will be tested to evaluate their effectiveness and efficiency in the field of geo-hazard monitoring and risk assessment.

EGU2020-11214
https://doi.org/10.5194/egusphere-egu2020-11214
EGU General Assembly 2020

Identifying Heritage Sites using Data Fusion on Location of Spiritual Sites and Geodata: A Case Study of Archeological Investigations in Brunei Darussalam

Kazimierz Becek[1], **Khairunisa Ibrahim**[2], and Joanna Krupa-Kurzynowska[3]
[1]Geoengineering, Mining i Geology, Wroclaw University of Science and Technology, Wroclaw, Poland, (kazimierz.becek@pwr.edu.pl)
[2]Faculty of Arts and Social Sciences, Universiti Brunei Darussalam, Brunei Darussalam, (Khairunisa Ibrahim)
[3]Geoengineering, Mining i Geology, Wroclaw University of Science and Technology, Wroclaw, Poland, (joanna.krupa-kurzynowska@pwr.edu.pl)

Human civilization and culture on Borneo had generally developed in strong spatial relationship with rivers. Borneo rivers, almost constantly filled in by heavy tropical rains, were ideal topographic features for humans to build their dwellings over and along their banks. Also, as the rivers were full of fish and the banks rich in sago palms and animals, they provided a diversified livelihood for the population limiting agricultural activities. The rivers were also almost exclusive means of transportation to support the trade. These spatial constraints successfully harnessed by the Borneo population ensured the size of the human footprint remained small, thus maintaining the pristine forests with only a very limited space taken up by human settlements. Construction materials for houses were exclusively forest products, which tend to decay quickly because of the high humidity and air temperature. The only durable remains of abandoned human settlements are pottery, clay deposits, some stone and metal objects brought from the North, e.g., China. Therefore, the quest to uncover the cultural heritage of Brunei Darussalam is an extremely challenging one. In this contribution, we report on an attempt to use remote sensing and geoinformation to identify the most likely locations of long-abandoned human settlements. An initial data set is the location of cemeteries and mosques. Besides, topographic data, including LiDAR data, the location of rivers and ponds, abandoned rice fields, landslides, secondary forest plots, historical records, are utilized. Developed maps from this geodata will support possible subsequent archaeological investigations by helping to identify the location of sites of interests. The outcomes of this project may be of interest not only to government departments in charge of the historical and cultural heritage of Brunei Darussalam but also to ecologists documenting the interactions between human civilization and nature.

EGU2020-13739, updated on 29 Apr 2020
https://doi.org/10.5194/egusphere-egu2020-13739
EGU General Assembly 2020

Satellite monitoring of ground and structure deformations applied to Colosseum archaeological park

Alfonsina Russo[1], **Irma Della Giovampaola**[1], Daniele Spizzichino[2], and Gabriele Leoni[2]
[1]Colosseum Archaeological Park, Piazza S.Maria Nova, 53 00186 Rome (irma.dellagiovampaola@beniculturali.it)
[2]ISPRA, Roma, Italy (daniele.spizzichino@isprambiente.it)

Archeological sites and cultural heritage are considered as critical assets for the society, representing not only the history of region or a culture, but also contributing to create a common identity of people living in a certain region. In this view, it is becoming more and more urgent to preserve them from natural and anthropogenic hazard as well as from negative effects due to climate changes. In the present paper, we will focus on ground deformation measurements obtained by satellite SAR interferometry and on the methodology adopted and implemented in order to use the results operatively for conservation policies in the Colosseum Archaeological Park (PAC). The integrated monitoring project of the PAC was inspired by the desire to build a system of protection and conservation at the service of sustainable exploitation. With these objectives, the PAC has launched a static and dynamic monitoring project consisting of five pillars: i) a dedicated database of all the historical and archaeological data of the monuments, (digital documentation archive implementation); ii) implementation of visual monitoring activities, (a dedicated app will allow to send data to the central system); iii) satellite monitoring program (historical and routine analysis of the satellite data) that will flow directly into the system and will be analysed in order to monitor possible ground deformation; IV) in situ monitoring from traditional ground diagnostic instruments; v) experimental activities, such as the use of H-BIM applications. Basically, the project carried out the creation of a multi-parameter system of permanent monitoring of the whole archaeological area, with associated indicators of risk level, for which it is necessary the combined use of new technologies. Some examples of satellite monitoring application will be presented and illustrated in order to stress the roles of new Earth Observation technologies in the field of conservation and maintenance polices. Considering the limitations of all the interferometric techniques, in particular the fact that the measurement is along the line of sight (LOS) and the geometric distortions, in order to obtain the maximum information from interferometric analysis, both ascending and descending geometry have been used. The interferometric techniques need to use a stack of SAR images to separate the deformation phase contributions from other spurious components (atmospheric, orbital, etc.). The objective is to find a nominal behavior of the site in response to critical events and/or related to natural degradation of infrastructures in order to prevent damages and guide maintenance activities. The first results of this cross correlated analysis showed that some deformation phenomena are identifiable by SAR satellite interferometric analysis and it has also been possible to validate them on field through a direct survey.

EGU2020-16549, updated on 29 Apr 2020
https://doi.org/10.5194/egusphere-egu2020-16549
EGU General Assembly 2020

Advanced multi-source approach for cultural heritage assessment and monitoring – the case study of the Corvin Castle and its surroundings

Cristian Moise[1], Cristina Elena Mihalache[1], Luminita Andreea Dedulescu[2], Andi-Mihai Lazăr[2], Alexandru Badea[2], and Iulia Florentina Dana Negula[2]

[1]University of Agronomic Sciences and Veterinary Medicine of Bucharest, Romania

[2]Romanian Space Agency, Bucharest, Romania

Remote sensing has already proven to represent an invaluable resource for monitoring the cultural heritage objectives by using non-invasive methods, thus enhancing the capabilities of safeguarding cultural heritage sites. Multiple types of data provide a better insight for the cultural heritage monitoring. Increasing human industrial activities in the vicinity of the Corvin Castle puts a question mark on the long-term conservation of the historic monument. Satellite imagery provides a large amount of data regarding the castle itself and its surrounding areas, enabling authorities and decision makers to assess the natural or anthropic hazards and mitigate potential damages. Freely available high-resolution satellite imagery that spans from mid 1970s until the present day enables an unprecedented opportunity for the creation of multi-sensor, multi-temporal and cross analysis.

In the field of cultural heritage and archaeological research, Light Detection and Ranging (LiDAR) is a significant technology that provides comprehensive data. LiDAR sensors acquire high-precision 3D information (point cloud) of the land surfaces and buildings.

Knowledge of structures stability is essential in early recognition of potential risks and enables preventive diagnosis of heritage sites. Vertical displacements in wide or remote areas can be identified using Persistent Scatterer Interferometry (PS-InSAR) technique. Measuring millimetric displacements using multi-temporal series of data acquired by spaceborne active sensors is less time consuming compared with in-situ measurements. The two-satellite constellation Sentinel-1 mission offers a 6-day exact repeat cycle at the equator, thus providing fast and high accuracy results for emergency situations and hazards monitoring, suitable for PS-InSAR processing. Monitoring the structure stability of this historical monument is of great importance.

The Corvin Castle, also known as Hunyadi Castle or Hunedoara Castle, is the most spectacular Gothic-style construction in Transylvania, Romania. Today, the castle is a rare historical and architectural example. Built in the mid-15th century, the Corvin Castle is split into three large areas: The Knight's Hall, the Diet Hall, and the circular stairways. Each of these three parts is surrounded by both circular and rectangular towers that were used for both defense and as a

prison.

This paper presents the ongoing activities of bringing together various geospatial technologies and data sources in order to set-up an integrated approach for site monitoring and risk assessment related to the Corvin Castle and other similar cultural heritage objectives. The outcomes will provide significant contributions for implementing suitable protection and preservation measures.

EGU2020-17498, updated on 29 Apr 2020
https://doi.org/10.5194/egusphere-egu2020-17498
EGU General Assembly 2020

Monitoring of moisture levels with microwave sensors at the carved rock town Uplistsikhe, Georgia

Stefanie Fruhmann[1], Giorgi Basilaia[2], Mikheil Elashvili[2], Tea Munchava[2], and Oliver Sass[3]
[1]University of Graz, Department of Geography and Regional Science, Graz, Austria (stefanie.fruhmann@uni-graz.at)
[2]School of Natural Sciences and Engineering, Ilia State University, Tbilisi, Georgia
[3]Chair of geomorphology, University of Bayreuth, Germany

A variety of weathering processes is controlled by moisture movements in porous rock. However, the quantitative assessment of small-scale moisture levels and fluctuations in-situ, over longer time periods, is still a challenge. The aim of our investigation is to close this gap with a microwave-based moisture monitoring system, installed at the cave town Uplistsikhe in Georgia, which oldest structures date back to the early Iron Age (10^{th}-9^{th} centuries BC).

Two morphologically different cave structures were equipped with two pairs of sensors, each covering two depth ranges, at two positions to detect different moisture contents and sources. These are considered the main driver of the highly accelerated weathering processes and decay of Uplistsikhe.

With the long moisture monitoring dataset of 12 months, combined with meteorological data from the study site, seasonal moisture variations and environmental-rock interactions are detected. Preliminary data from the first eight months of monitoring is presented.

EGU2020-18154
https://doi.org/10.5194/egusphere-egu2020-18154
EGU General Assembly 2020

Cultural heritage monument complex monitoring data analyses using machine learning algorithms

David Kvavadze, Giorgi Basilaia, Tea Munchava, Giorgi Laluashvili, and Mikheil Elashvili
Cultural Heritage and Environment research center, Ilia State University, Georgia

Cultural heritage monuments, that were created by mankind for centuries are scattered throughout the world. Most of them are experiencing impacts coming from nature and humans each year that result in damage and changing their common state. Many of the monuments are facing critical conditions and require diagnostics, study and planning and management of conservation/rehabilitation works. Due to the impact of environmental factors such as temperature, humidity, precipitation, the existence of complex structure of cracks, infiltrated water and runoff water streams, together with active tectonics in the region, Uplistsikhe and Vardzia rock-cut city monuments located in Georgia face problems and permanent destruction.

We have developed continuous monitoring systems that are installed in Vardzia and Uplistsikhe.

These systems are generating large amounts of data and it is almost impossible to analyze this data using conventional methods. In parallel with technological development, it is now possible to analyze big data using machine learning. We decided to use machine learning to address our problem. This approach gave us some interesting results. We were able to detect correlations between different sensors, see anomalies in data that gave us some clues about hazard zones. Additionally models and predictions about the monument's condition were made.

Our work shows that machine learning could be used to estimate conditions make predictions about monuments state.

This work was supported by Shota Rustaveli National Science Foundation of Georgia (SRNS) [Grant Number fr17_90]

EGU2020-18511
https://doi.org/10.5194/egusphere-egu2020-18511
EGU General Assembly 2020

IoT systems for the study of cultural heritage monuments - case of Uplistsikhe, Georgia

Tea Munchava, Giorgi Basilaia, Nikoloz Vacheishvili, David Kvavadze, David Chkhaidze, and Mikheil Elashvili
Cultural Heritage and Environment research center, Ilia State University, Tbilisi, Georgia

Cultural heritage monuments, that were created by mankind for centuries are scattered throughout the world. Most of them are experiencing impacts coming from nature and humans each year that result damage and changing their common state. Many of the monuments are facing the critical condition and require diagnostics, study and planning and management of conservation/rehabilitation works. Due to impact of environmental factors such as temperature, humidity, precipitation, existence of complex structure of cracks, infiltrated water and runoff water streams, together with active tectonics in the region, Uplistsikhe rock cut city monument located in central part of Georgia faces problems and permanent destruction.

In parallel with technological development, it is now possible to conduct complex monitoring of the environment parameters in real time using sensor systems, data acquisition, communication network, data visualization and processing methods.

Complex approach with equipment used in research and experiment was used to study various factors affecting the monument and presents the very important issue. Gained experience, research methodologies and technical skills will be good basement for future study/research projects on similar monuments as the collected information gives us an in depth understanding of processes that impact on the monument and can then be followed by a coherent plan of risk reduction to increase the effectiveness of the used solutions.

During the study of cultural heritage monuments, there are some technical limitations that can occur: The electricity or communication wiring might not be available on the site or the wiring is impossible without damaging the monument itself. So, there is a rising need of low power wireless sensor acquisition and transmission systems.

Paper discusses the usage of IoT based sensor systems for study of Uplistsikhe Cultural heritage monument. The built system uses low power data transmission network based on LoRa standard.

Measurement points were selected where several parameters (Temperature, Humidity, Crack meter value) are acquired and sent to the central information platform using so called Internet of things.

Central web-built system that is based on open platform Grafana is responsible for the data

storage, visualization, processing and alarm generation.

The statistical processing of acquired collected data resulted in calculation of the parameter ranges. Calculations were made on the 24-hour data of each day to calculate the variations. First the maximal and minimal recorded values were identified, then the difference between maximums and minimums were calculated. Additionally, the mean values and the standard deviations were calculated resulting to the ranges considered as normal, excessive, dangerous and critical parameters.

These parameters were integrated into the web-system. In case of dangerous and critical parameters the system is able to distribute alarm state information via several channels such as email, chat message, SMS or other means.

As a result, the low power wireless system sensor measurement system was created that sends acquired data it to the cloud-based web platform with possibility of the data processing and issuing alarms.

This work was supported by Shota Rustaveli National Science Foundation of Georgia (SRNSFG) [Grant Number fr17_90]

EGU2020-18918
https://doi.org/10.5194/egusphere-egu2020-18918
EGU General Assembly 2020

Modeling Surficial Water runoff and estimation of its damaging factor on Rock Curved Cultural Heritage Monuments of Georgia – Application of Close Range Aerial Photogrammetry

Akaki Nadaria, **Giorgi Kirkitadze**, Mikheil Lobjanidze, Nikoloz Vacheishvili, and Mikheil Elashvili
Cultural Heritage and Environment Research Center, Ilia State University, Tbilisi, Georgia (info@iliauni.edu.ge)

Rock curved monuments of Georgia, represent a unique cultural heritage – an ancient cities, churches and kelly carved in rock, painted and decorated by hermit monks, which unites architectural monument and Natural-Geological complex. Such monuments are particularly vulnerable and their restoration and conservation requires a complex approach. These monuments, as many other similar monuments worldwide, is subjected to slow but permanent process of destruction, expressed in several main factors, one of which is rock weathering caused by surface rainwater runoff and water infiltration, coupled with temperature variations.

Close Range Aerial Photogrammetry, with its actively developing applications has been used to address this problem. Several Rock Curved Monuments of Georgia: Vardzia (12th Century), Vanis Qvabebi (8th Century) and Uplistsikhe (Late bronze period) were studied. First two of which represent large Monastery complexes curved in Volcanic tuff and tuff-breccia, while the Uplistsikhe represents ancient Rock Curved town, constructed in a coarse-grained week sandstone, with roots deep in the history of Georgian state.

To achieve sustainable preservation of cultural heritage rock-curved monuments, this particular type of danger should be addressed: Preservation of structural integrity of monument and avoiding ground or surficial water infiltration is substantial to preserve unique mural paintings and wall inscriptions, still preserved in these Rock Curved Monuments.

High-resolution Digital Elevation Models and Orthographic Aerial Photo images (in vertical and horizontal perspectives) were constructed through several aerial missions. Spatial data was accurately Georeferenced using the DGPS RTK system and Total Station (for vertical cliffs). The obtained data serves as an input for the Hydromodeling of Surficial water runoff, calculated using the ArcMap Hydro tool extension. Moreover, high-resolution photo textures allowed to estimate the damaging effect of formed water channels and crack systems of water infiltration. Conceptual solutions of water drainage systems allowing surficial water diversion and mitigation of its effect on rock strata were elaborated and even constructed in the case of Vardzia. Aerial Photogrammetry as a tool for routine periodic inspection has been adopted for the given monuments, where the damaged areas are hardly accessible by foot and even highly dangerous for the access of rock climbers.

EGU2020-19435
https://doi.org/10.5194/egusphere-egu2020-19435
EGU General Assembly 2020

Applying InfraRed Thermography (IRT) for the protection and conservation of rupestrian CH sites affected by slope instabilities

William Frodella, Daniele Spizzichino, Giovanni Gigli, Mikheil Elashvili, Claudio Margottini, and Nicola Casagli

Department of Earth Sciences, University of Florence, Florence, Italy (william.frodella@unifi.it)

Rupestrian Cultural Heritage (CH) sites were among the first man-made works in the history of humanity, therefore playing a key role in building the memory and roots of human society. These sites were often carved in slopes formed by soft rocks, which due to their peculiar lithological, geotechnical and morpho-structural features are often prone to weathering, deterioration and slope instability issues. The use of advanced remote sensing (RS) techniques combined with traditional methods (e.g. field surveys, laboratory analysis), can provide fundamental data to implement a specific site-specific and inter-disciplinary approach for the sustainable protection and conservation of rupestrian CH sites. In this context Infrared Thermography (IRT), thanks to the technological development of portable high-resolution and cost-effective thermal imaging cameras, can be profitably used for the detection of CH conservation issues (namely fractures, water seepage, moisture and surface weathering). In this paper several applications of IRT in integrated methodologies for rupestrian sites conservation in mountainous regions of Georgia will be presented. The aim of this work is to evaluate the potential of IRT in the field of CH protection and conservation strategies, in order to provide a useful versatile and low-cost tool, to be profitably used in management plans of rupestrian CH characterized by similar contexts. Advantages and constraints of the adopted method will be discussed, as well as general operative recommendations and future perspectives.

EGU2020-19773
https://doi.org/10.5194/egusphere-egu2020-19773
EGU General Assembly 2020

Assessing geo-hydrological hazards with Remote sensing data in Antananarivo (Madagascar) historical center

Andrea Ciampalini[1], William Frodella[2], Daniele Spizzichino[3], Claudio Margottini[2], and Nicola Casagli[2]

[1]University of Pisa, Earth Sciences Department, Italy (andrea.ciampalini@unipi.it)
[2]University of Firenze, Earth Sciences Department, Italy (william.frodella@unifi.it; claudio.margottini@unifi.it; nicola.casagli@unifi.it)
[3]ISPRA, Geological Survey of Italy, Italy (daniele.spizzichino@isprambiente.it)

Landslides represent a major threat in Madagascar, especially in the central and eastern regions during the rainy season (from November thru May), when heavy rains from tropical storms and cyclones saturate the soil making mountains and hillsides more susceptible to slope instability phenomena. The capital Antananarivo has been particularly affected by geo-hydrological risks in the last years, with special regards to the March 2015 event, when cyclones triggered diffuse flooding and landslides causing damages, casualties and over 20000 evacuees. Antananarivo area is characterized by the most important historical and cultural heritages in Madagascar, such as the ancient fortifications and palaces at Ambohimanga (located just 20 km north of the town area), protected as an UNESCO World Heritage site since 2001, and the Rova of Antananarivo royal palace complex. Antananarivo was called Analamanga (the "blue forest"), until 1610, when the merina King Andrianjaka built his palace on the highest hill of the city, and built the first Rova (meaning “fort” in Malagasy) to post a garrison of 1000 man. Antananarivo developed from the site of the first Rova at the top of Analamanga hill at about 1480 m a.s.l., becoming the current historical core (the Upper town or the “Haute Ville”), gradually spreading over the whole Analamanga hill slopes (Middle town or the “Ville Moyen”).

In October 2017, a geo-hydrological hazard mapping was performed in the Upper Town by combining field surveys, remote sensing and geomatic data analysis. The output of the performed activities consisted in the creation of a detailed geodatabase, which by means of geomatics methods was integrated with field data, topographic data, high resolution digital terrain models (2 and 1 m spatial resolution), very high resolution optical satellite images (Pleiades-1A with 0.5 m resolution) and homogenized in a Geographic Information System (GIS). This geodatabase represents a fundamental tool for susceptibility, hazard and risk assessment/management activities to be performed in the Antananarivo hill area for a proper management of its cultural and historical heritages.