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THE CONTRIBUTION OF INFORMATION TECHNOLOGIES TO THE PROTECTION OF WORLD CULTURAL AND NATURAL HERITAGE MONUMENTS "THE CASE OF ANCIENT PHILIPPI, GREECE"

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ABSTRACT

Natural and man-made disasters are happening more and more often, leading to hundreds of casualties and significant catastrophic consequences. Unfortunately, they are affecting not only urban centers, outdoor settlements, and infrastructure, but also world cultural and natural heritage sites. Many of these monuments, which are included in the UNESCO World Heritage List, are at risk due to even moderate natural or man-made hazards, given the structural vulnerability created over the course of their hundreds or even millennia of existence. In this context, for several years, the issue of the risks of World Heritage sites has been of concern to UNESCO and in particular the World Heritage Center. Following this effort, the present work aims to enrich methods and techniques with the help of advanced information technologies and in particular a combination of Artificial Intelligence (AI), Virtual and Augmented Reality, and the Internet of Things (IoT). The article presents the first steps towards a holistic and easily adaptable methodology, forming the so-called INBO (**IN**DEX + **BO**OKLET = INBO), a novel combination of INDEX (catalogue) and IT Booklet, which will allow both monument monitoring and real-time emergency response. This methodology will improve the way in which first responders and monument managers, even visitors, react and handle the information provided. INBO will allow the right prognosis to be achieved by leading to timely and smart decisions that will help prevent potential damage to the cultural heritage. The Ancient City of Philippi will serve as a pilot study for the approach. The archaeological site of Philippi, located in Northern Greece, is one of the heritage sites, listed on the UNESCO World Heritage List.

KEYWORDS: Artificial Intelligence, Risk Assessment, Heritage Protection, INDEX, UNESCO, Monuments, INBO

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1. INTRODUCTION

In recent decades the number of disastrous natural phenomena (floods, fires, earthquakes and others) as well as man-made disasters has increased, causing both social and economic problems and adverse effects on cultural heritage, affecting world Cultural and Natural heritage sites. Many of these Monuments are at risk due to even moderate natural or man-made hazards, given the structural vulnerability created over the course of their hundreds or even millennia of existence. To this end, novel approaches that could assist on protecting them is undoubtedly imperative. In this context, for several years, the issue of the risks of World Heritage sites has been of concern to UNESCO and in particular the World Heritage Center. The result of the effort was the compilation of a manual guide, written with the help of experts. This guide lists the hazards, their special features and their impact on cultural monuments and people. Following this effort, the present work aims to enrich methods and techniques with the help of advanced information technologies and in particular a combination of Artificial Intelligence (AI), Virtual and Augmented Reality, and the Internet of Things (IoT).

The current work designs, develops and presents the first steps of INBO, a methodology that brings together artificial intelligence, risk assessment techniques and even stakeholders. The proposed smart awareness and management solution, based on accurate information and the right knowledge, will be able to automatically make or propose the right actions and decisions. More specifically, the article clarifies the added value of the approach focusing on augment reality and the intelligent agent technology that acts as a virtual alter ego of our world without the limitations of the human factor.

The first stage of the methodology includes the development of an INDEX for each monument and its potential hazard levels, including monument features such as marshlands in the ancient city of Philippi, and potential types of hazards such as floods. The risks will be classified and prioritized, customizing the protection actions. The next stage involves the development of the IT Booklet, where initially with the use of augmented and virtual reality the monument will be reproduced, providing awareness to the public and visitors. This part will demonstrate risky locations while evacuation plans will be provided. Next, IoT and Artificial Intelligence will support the designed and developed of a smart real-time control application that will enable monitoring and management of the monument using appropriate equipment and software. This pert will include the appropriate IoT equipment, collecting and reasoning on data, smart real-time control applications, as well as AI techniques for stakeholders.

This paper discusses upon the first INDEX stage as well as the first step of the second stage, that of the Augment and Virtual reality module. Furthermore, the Ancient City of Philippi serves as a pilot study for the approach. The archaeological site of Philippi, located in Northern Greece, is one of the heritage sites, listed on the UNESCO World Heritage List. This monument is endangered not by common natural risks but by a particular phenomenon that of the flooding of the Marshlands of Philippi.

The article is organized as follows, section 2 presents an overview of the INBO methodology, and section 3 discusses augment and virtual reality. Section 4 presents an overview of IoT in the context of INBO approach while section 5 discusses the case of Ancient Philippi, Greece. Finally, section 6 discusses related work while section 7 summarizes the added value of the article with some final remarks.

2. THE INBO APPROACH

The INBO approach, developed by members of this team, brings forward a holistic and easily adaptable methodology that combines edge technology with risk assessment techniques. The main purpose of INBO is to prevent potential damage to the Cultural and Natural heritage sites by enabling the right prognosis leading to timely and smart decisions. Following this methodology, first responders, heritage stakeholders, as well as visitors will be able to improve the way, in which they react and handle the provided information.

INBO is a three-stage methodology that includes an INDEX and an IT Booklet, (**IN**DEX + **BO**OKLET = INBO) which allows both monument monitoring and real-time emergency response. Fig. 1 depicts the main stages of the methodology. The first stage aims at the monument studying. The second stage reproduces the site purposes of public awareness. The third stage monitors and manages the site using Artificial Intelligence (AI) technologies, such as the Intelligent Agents and the Internet of Things (IoT) (Kravari & Bassiliades, 2019). This holistic smart awareness and management approach will be able to automatically make or propose the right actions and decisions, supporting managers and stakeholders.

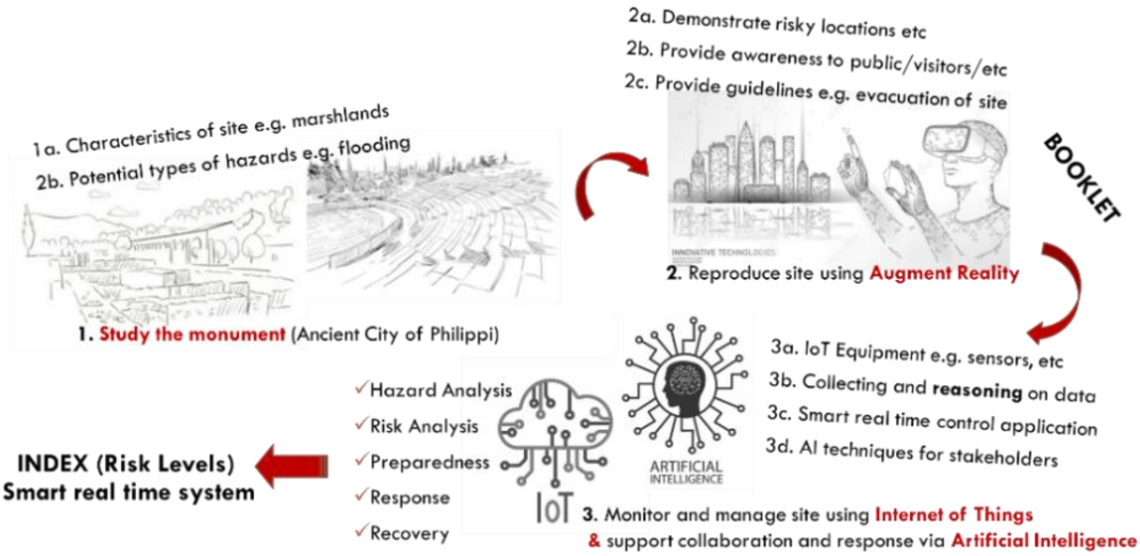
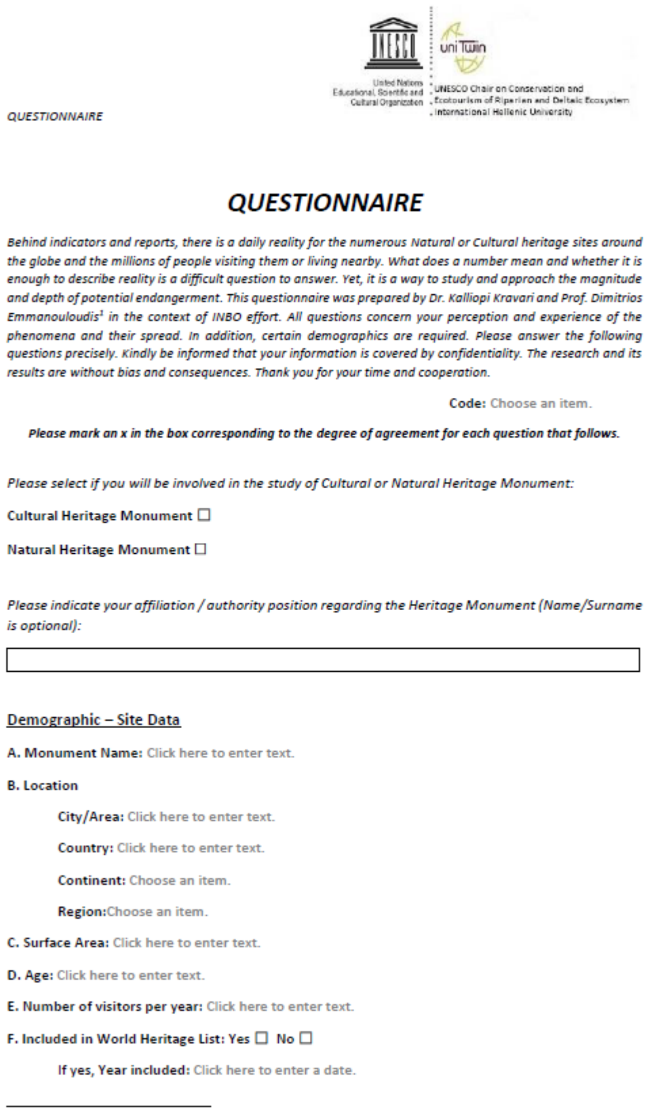


Figure 1. The overview of the INBO methodology.

3. INDEX

The first phase of the methodology includes the development of an INDEX for each Monument. This stage will identify, record, classify and prioritize the dangers that threaten a Monument or an Archaeological site. To this end, an appropriate questionnaire will be shared to site managers and responsible stakeholders. The first page of the questionnaire is presented below indicatively (Fig. 2). This questionnaire will collect data related to natural hazards, such as hurricanes, lightning, flash floods, landslides etc., natural-human induced hazards, such as agro and forest fires, man – made hazards, such as air, water pollution, and technological risks, such as IT Protection Systems failure. Upon the completion of the questionnaires, referred to a specific heritage site, INBO methodology proceeds with the analysis based on artificial intelligence (AI) techniques. Beyond the assessment and forecast results, INBO will also provide brief guides (Behavior Codes) for visitors and site stakeholders that will contain instructions for protection and/or survival from all the important and most frequently occurring risks of Natural and Technological Disasters. In this context, the advice offered through these Guides will be supervisorial enhanced with the help of technologies such as augmented reality (AR) videos and animations. This way, stakeholders and visitors will be better prepared and more familiar with what they should do in case of the Monument, the Archaeological site, and the wider area or even their life is threatened.



QUESTIONNAIRE

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QUESTIONNAIRE

Behind indicators and reports, there is a daily reality for the numerous Natural or Cultural heritage sites around the globe and the millions of people visiting them or living nearby. What does a number mean and whether it is enough to describe reality is a difficult question to answer. Yet, it is a way to study and approach the magnitude and depth of potential endangerment. This questionnaire was prepared by Dr. Kalliopi Kravari and Prof. Dimitrios Emmanouloudis[1] in the context of INBO effort. All questions concern your perception and experience of the phenomena and their spread. In addition, certain demographics are required. Please answer the following questions precisely. Kindly be informed that your information is covered by confidentiality. The research and its results are without bias and consequences. Thank you for your time and cooperation.

Code: Choose an item.

Please mark an x in the box corresponding to the degree of agreement for each question that follows.

Please select if you will be involved in the study of Cultural or Natural Heritage Monument:

Cultural Heritage Monument ☐

Natural Heritage Monument ☐

Please indicate your affiliation / authority position regarding the Heritage Monument (Name/Surname is optional):

Demographic – Site Data

A. Monument Name: Click here to enter text.

B. Location

City/Area: Click here to enter text.

Country: Click here to enter text.

Continent: Choose an item.

Region: Choose an item.

C. Surface Area: Click here to enter text.

D. Age: Click here to enter text.

E. Number of visitors per year: Click here to enter text.

F. Included in World Heritage List: Yes ☐ No ☐

If yes, Year included: Click here to enter a date.

Figure 2. Part of the INBO questionnaire.

4. IT BOOKLET

The second phase of the methodology includes the development of a two-stage IT Booklet, where initially with the use of augmented and virtual reality the Monument will be reproduced, providing awareness to the public and visitors, as well as stakeholders. This part will demonstrate risky locations while evacuation plans will be provided. Next, the Internet of Things and Artificial Intelligence will support the design and development of a smart real-time control application that will enable monitoring and management of the Monument using appropriate equipment and software (Astorga González et al., 2020). This part will include the appropriate IoT equipment, collecting and reasoning on data, smart real-time applications, and AI techniques for stakeholders. As a result, INBO provides a **custom-made** smart real-time system, which included **five (5) modules, namely** Hazard Analysis, Risk Analysis, Preparedness, Response and Recovery. Yet, it is out of the scope of this article to analyze each of these modules and technologies; hence this article discusses further mainly on the preparedness and response modules.

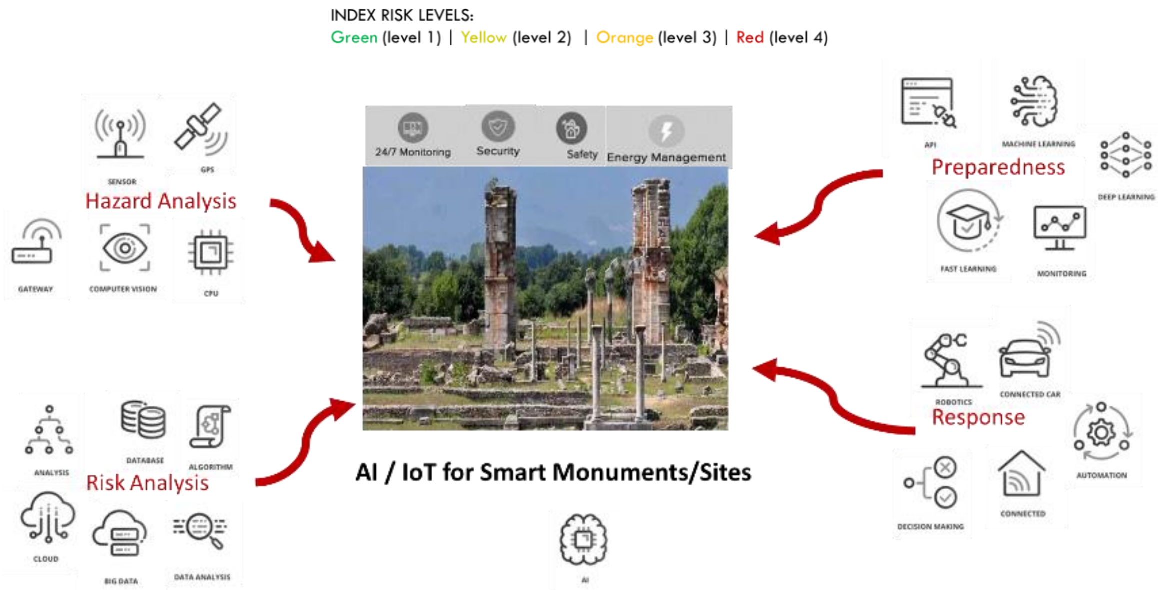

Figure 3. INBO Smart real-time system main technologies.

5. AUGMENT AND VIRTUAL REALITY

Over the past years, many initiatives have been focusing on Information Technology (IT) and its potential use for the management and protection of heritage in a variety of aspects. Such an initiative is the so-called Smart Heritage, a relatively new system and management media that initiated by INTACH Heritage Academy to answer the challenge that addresses the Cultural Heritage Conservation in the Smart City Era by using the advancement of Information Communication Technology (ICT) (Mehta & Piplani, 2017). The aim of the Smart Cultural Heritage is to serve the preservation of identity, tangible and intangible, of sites and communities using smart technologies, since technological advancements have already led to a variety of achievements (Siountri et al., 2018). In this context, digital networking of institutes, associations and organizations, visitors, and cultural objects is already common while crowdsourcing information, related to monuments, trails, customs, anthropogeography provides databases and digital paths.

Furthermore, access to cultural objects and e-learning gains more attention by providing (a) production of virtual and mixed reality applications, documentation, videos, 3D models, hiking trails, b) production of audiovisual material and 3D movies, and c) visit to virtual museums. Moreover, digitizing the material and developing tools for analyzing and searching for information can support cultural heritage institutions, such as libraries and museums, creating large data repositories that will allow access to the preservation of cultural heritage. To this end, IT techniques can even support research upon revealing hidden information of the past, bringing to light hidden collections, or uniting antiquities that are spatially remote. However, since technology is constantly changing, the imperative need is to develop local Smart Cultural Heritage strategies and tools to enhance and preserve cultural and environmental resources, which will be integrated with the local Smart City plans (Jelinčić & Glivetić, 2019). In this context, augmented (AR) and virtual (VR) reality technology is able to provide a significant advantage in the field of monument management and protection.

Figure 4. AR tour Kavala Helexpo (2014)

A case in that VR was successfully used for educational purposes was when the IHU AETMA Lab allowed students to design their own school models, helping them to understand better how they should react to a potential threat, such as an earthquake. This project is called Virtual School and uses augmented and mixed reality experiences in order to raise students' awareness of natural disaster management. Virtual schools make use of high-end technology to achieve the aforementioned goals while, at the same time, it makes technology free for schools. This Virtual application led us to think about using it for museums and archaeological sites starting from the area of Philippi. In this context, firstly, was implemented an Augmented Reality (AR) tour for Kavala (Greece) Helexpo 2014 (Fig. 4).

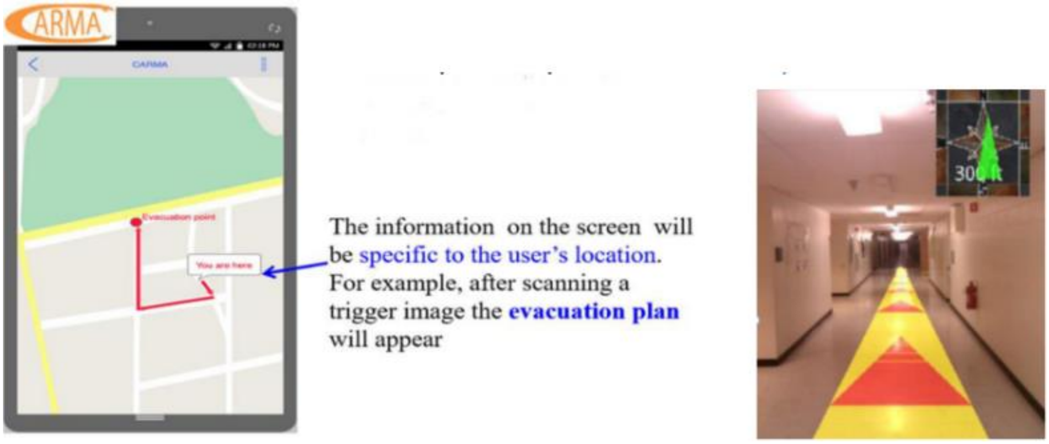

Figure 5. CARMA AR project in the ancient area of Philippi, Greece by AETMA Lab IHU

Following the AR tour, an AR approach for the museum was implemented, too. This approach is called CARMA (Fig. 5) and it is able to inform the visitors of the Museum of Philippi or of an open space, for their location and the optimum exploration paths, or evacuation plans in case of a risk.

6. INTERNET OF THINGS & INBO SYSTEM

The Internet of Things (IoT) aims to create a world where everyone and everything, called Things, will be connected and the knowledge will be effortlessly diffused in every direction (Mukhopadhyay & Suryadevara, 2014). It has the potential to change our daily lives. It is a world, although still at an early stage, that forms a huge, open and distributed network of Things. Things able to make decisions and communicate. However, the open and distributed network combined with the enormous heterogeneity of things raises important challenges. Challenges that can find an answer to Artificial Intelligence, which can add autonomy, context awareness and intelligence, realizing the vision of IoT. On the other hand, every year millions of people visit monuments, museums and art exhibitions, hence the need for novel monitoring and protecting heritage solutions is obvious. In this context, the IoT has already shown tremendous potential in monitoring cultural heritage environments (Khan et al., 2020). It has been successfully used to monitor the structural health of buildings, cultural preservation and revitalization as well as to improve the experience of users of the cultural environment.

	Natural	Human-induced	Indirect / secondary
Meteorological	Hurricane Lightning Heavy precipitation		Flooding (coastal / rivers) Fire Mass movement
Hydrological (caused by high rainfall)	Flash flood Landslide / volcanic ash / lava / ice damming of a river Tsunami	Hydrological infra-structure failure (dams, levees, reservoirs, drainage systems) Coastal protection failure (sea walls)	Disease epidemic Pollution
Volcanic	Lava flows Pyroclastic flows Ash and block falls Gases	Mining-induced (e.g. mud volcano)	Lahars (mudflows) Landslides Tsunami Fire
Seismic	Faulting Transient shaking Permanent deformation (e.g. folds) Induced movement (liquefaction and mass movement)	Dam- and reservoir-induced mass movement Mining-induced Explosion / nuclear induced	Mass movement Fire Flood
Mass movement (of snow, ice, rock, soil mud, etc.) (induced by slow-acting erosion or one of the above)	Falls Slumps Slides Flows	Unstable mining / construction waste spoil heaps	

Figure 6. UNESCO Relationships of natural hazards and man-made hazards

In this context, INBO uses the IoT, combined with Artificial Intelligence, in order to form the final stage of its contribution (Fig 1). The first step towards this direction was to reveal relationships of natural and man-made hazards to potential risks. For this purposes, UNESCO classifications were studied (Fig. 6), revealing that IoT could deal with various challenges based on these categories. INBO proposes each heritage site, based on a custom study, to be equipped with appropriate IoT devices, enabling a smart network in which all entities will communicate and share knowledge. Yet, although IoT technologies cannot stop disasters from happening, they can be very useful for disaster preparedness, by prediction and early warning systems, and response by organizing response and recovery. So far, INBO includes a variety of IoT solutions that can be adapted to specific monument cases based on the risks that they face. The INBO IoT study mitigates many of the emergency challenges, such as a weak communication network and delays due to lack of information and data. Various hazard sensors, such as fire, flood, earthquake, and so on, can be used while local emergency rescue services can be alerted via a cloud service where everything will be connected. Mention that the decision upon which IoT solution is appropriate for a specific case is the result of the first INDEX stage of INBO methodology.

For instance, regarding the monitoring and management of meteorological - hydrological hazards a synergy of GIS and IoT could deal with weather disasters. Smart devices and applications from daily life could be used for such cases. Data is usually measured and collected by distributed sensors, placed in different locations. The collected data will be processed by INBO IoT applications while the system generates alerts. A critical component is to provide dissemination via multiple mechanisms in near real-time to responsible entities and the public. Natural weather, such as hurricanes, forest fires, floods, volcanoes, tornadoes and earthquakes can be addressed through the aforementioned synergy. Usually, IoT (sensors) monitors natural weather events and notify about critical safety information. Sensor technology offers real-time information during and after a natural weather event occurs. For example, sensors capable of monitoring, are able to detect increased water levels before a hurricane and to track how quickly a forest fire is spreading.

However, we have to go beyond that. We use IoT not only to forecast but also to deal with issues related to hazards. For instance, pollution affect harbor sea water and entire area ecosystem which makes extremely important a constant and reliable monitoring of the (sea) waters. For example, hurricanes can increase in speed and intensity as they pass over warm water, which may pose a heightened risk to coastal cities. To this end, monitoring and warning systems including both hardware and software could be the answer. Such a system, developed by EVAE lab of International Hellenic University, provides a light-weighted ROUV (Remotely Operated Underwater Vehicle) equipped with a complete set of sensors in order to collect data and samples (Fig. 7) and a smart monitoring platform that will enable autonomous decision making/suggestion using artificial intelligence.

Figure 7. ROUV (Electric Vehicles and Automotive Electronics Lab of IHU)

Hence, INBO, based on the aforementioned technologies and AI techniques, proposes among others an early warning systems that includes four components, namely risk knowledge, monitoring, warning communication and response capability. Risk knowledge is a categorical system of hazard analysis that allows stakeholders and experts to prioritize local response efforts and manage their resources, moving smart automation a step further. Monitoring is the module that enables hazard identification, up-to-date environmental track changes in order to reflect the severity and expected outcome of the natural disaster. Warning communication is based on multi-channel communication protocols while response capability reveals that information alone cannot assure a positive outcome, hence we need technology and collaboration among involved parties.

7. PILOT STUDY - THE ANCIENT CITY OF PHILIPPI IN KAVALA, GREECE

The Ancient City of Philippi is the 16th and chronologically speaking the last Monument of Greece that was included in this list of UNESCO. This site serves as pilot study for our proposed approach. The archaeological site of Philippi, located in Northern Greece, is one of the heritage sites, listed on the UNESCO World Heritage List, which strongly consolidates its reputation as a unique place of extraordinary value for human civilization. It is an exceptional testimony to different historic periods and civilizations, from prehistoric times to Byzantine periods. What makes it unique is the assembly of the architectural heritage preserved at the site, representing various architectural types of monuments expressing the development of architecture during the Roman, Christianity, and Byzantine periods. The remains of the ancient city of Philippi represent a unique example of Roman architecture, with its specific configuration giving it attributes of a “small Rome”. Undoubtedly, the most impressive building of this period, despite the changes that it has undergone over the centuries, is the ancient theatre of Philippi (Fig. 8)

Figure 8. Ancient theatre of Philippi

This monument is significantly endangered neither by common natural disasters, e.g. fire, flood (from Flash Floods) or earthquake, nor by atmospheric pollution or other major pollutants. However, it is at risk because of a particular phenomenon of the flooding of the Marshlands of Philippi (Fig. 9) which are located both all around and just a few hundred meters away. This flood is periodic, every winter, while during the summer there is a total drought of the marshlands. The phenomenon of the constant rising and lowering of the surface water body for ongoing years with a particular increasing rate during the last decades is quite possible to lead to the activation of the subsurface soil water table circumferentially the Ancient Town. Thus, this activation could lead to the peril of the overall Geostationary Balance of the area with innumerous repercussions for the Ancient Settlement.

Consequently, all-year-round thorough measurements both of several soil and climate parameters but also, and most importantly, of soil and subsoil detailed factors are essential. The development of these measurements and their progress also determines either the existence, or lack, of a direct danger but also the course of the works for protection, even the way visitors may affect the area, especially when there is a load of 5,000-6,000 people with vehicles nearby (Ancient Theater Performances). Philippi Case study leads to the obvious as well as useful inference that all the natural and human-induced dangers do not appear in the same extent of threat for every Natural or Cultural Monument. So, in our case, the Ancient Town does not seem to be threatened by an extended forest fire or air pollution. On the contrary, Ancient Olympia, Greece is clearly threatened by an extended and uncontrollable Forest Fire, while the Acropolis in Athens faces problems with air pollution.

Figure 9. Flooding of the Marshlands of Philippi, Greece

8. USING INBO AT THE ANCIENT CITY OF PHILIPPI IN KAVALA, GREECE

First, a study is conducted about the ancient city of Philippi in Kavala and the marshlands, including among other the aforementioned questionnaire. The result is an INDEX which will be uploaded on a platform. There, it will be real-time updated through the continuous flow of incoming answers from questionnaires, as well as the analysis outcomes of these answers. Following this stage, proper AR guides for visitors and site stakeholders will be also uploaded (such as those discussed in section 3). Fig. 10 depicts a case of emergency in the museum of Kavala where there are important archeological findings of the ancient city. This example will depict better the added-value of the approach.

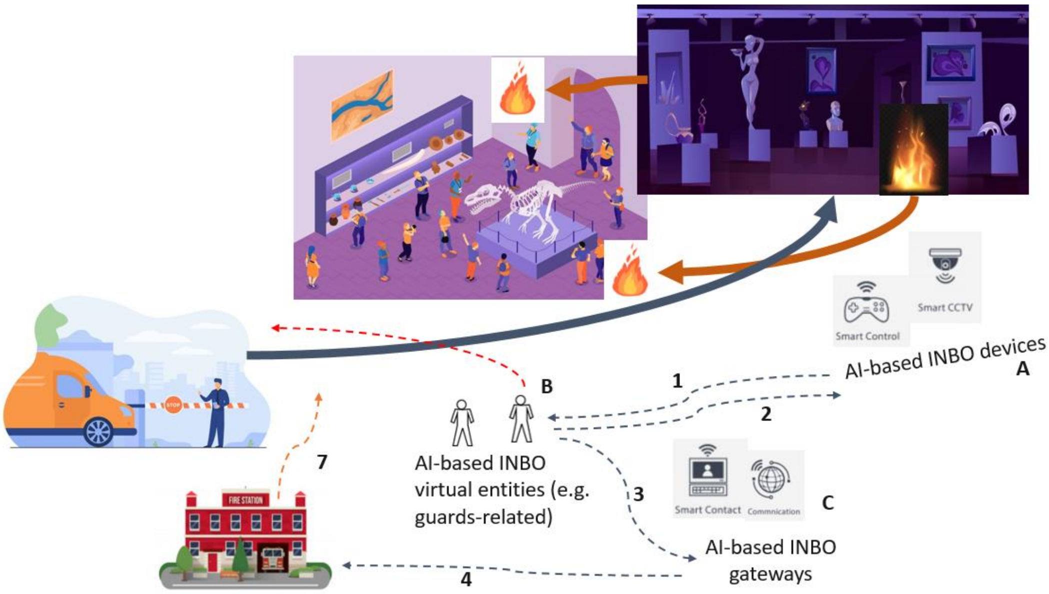

Figure 10. Emergency in the museum

Suppose that suddenly a fire breaks out in a closed hall. The security guard is outside checking an incoming vehicle, without a clue about the fire. Unfortunately, till the guard releases that a fire emergency occurs, the fire extends to the adjacent hall where there are visitors and significant historical findings. The security guard panicked, forgets to call the fire department, and the situation is out of control. The existence of an INBO installation on the other hand could provide better results. INBO provided intelligent software that can communicate and act upon goals. As a result, a variety of IoT sensors and devices such as cameras or automatic door mechanisms are automatically controlled. In this context, as soon as, the AI-based INBO devices detect the first fire, inform the appropriate AI-based INBO entity, e.g. the virtual guard in charge (line 1). On its turn, that entity reasons upon the data and extracts the conclusion that the hall must be sealed and the fire station should be informed. Hence, sends a message request to the appropriate device of the group A to close the door, activate the fire extinguishing system and play a voice message to visitors at the adjacent halls to move calmly outside the building (line 2) while another message is sent to the appropriate gateway (group C) asking it to inform the fire station (line 3), which is done immediately (line 4). Meanwhile, the human security guard. All-in-all, the INBO evaluated the situation real-time, communicated with the appropriate stakeholders coordinating their actions and informed the visitors, eliminating the human factor without time waste.

9. RELATED WORK

This proposal seems to have similarities with the LIFE – IP project that has been announced two years ago by Ministry of Environment (LIFE-IP AdaptInGR Project, 2021), but in fact is different. In Life – IP project five of the total 18 Greek Heritage sites investigated and only in relevance with the factors that affect Climate Change. Moreover, the proposed INDEX is something different from ICOMS – GOOGLE platform where five Heritage Sites presented and their Risks and Dangers are measured, monitored and analyzed. The proposed by us INDEX is much broader with a Universal character, aiming to include all monuments, but of course due to the huge information size, with a brief format. Hence, there is still a lack of a combination of an INDEX with monuments and their degree of threat from hazards and the Artificial Intelligence in order to provide a complete, fairly general-purpose smart system.

10. CONCLUSION

This article discussed upon INBO, a two-phase methodology that consists of an INDEX and an IT Booklet. INBO realizes an intelligent-based approach where both technical and practical guidelines and tools support the protection of Monuments and human lives. It limits the common disadvantages of the existing distributed human-based approaches, by combining distributed sensors with AI technologies, forming a custom-made IoT system able monitor, forecast and take decisions protecting monuments and lives. Yet, although this broad methodology provides valuable edge technologies, it needs the synergy of organization and stakeholders in order to provide accurate policies, prioritizing the needs of all involved stakeholders. In this endeavor, assistance from local, national, and international committees and organizations is needed, since we firmly believe that it is absolutely necessary to cooperate with those that face the everyday practical or policy challenges. As for future directions, our priority is to study the scalability the complexity of the methodology and the involved technologies as well as the scalability of the system. Hence, the proposed methodology will be further improved, in an attempt to reduce among others its complexity. To this end, our intention is to further study each module involved the INBO proposal.

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