The role AI in shaping the future of coastal heritage conservation.

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Introduction

According to the United Nations Office for Disaster Risk Reduction, during the 1998–2017 period, 5.3% of all global disasters originated from high temperatures, In other words, 82% of natural disasters during this period were climate related. The 2014 report by the Intergovernmental Panel on Climate Change (IPCC) clearly states that "Changes in many extreme weather and climate events have been observed since about 1950. Some of these changes have been linked to human influences, including a decrease in cold temperature extremes, an increase in warm temperature extremes, an increase in extreme high sea levels, and an increase in the number of heavy precipitation events in number of regions.

The IPCC believes that the influences of climate change will not be uniform across the globe but will rather vary among regions and that average global temperatures are expected to increase between 1.4 °C and 5.8 °C by 2100,.

Introduction

UN Office for Disaster Risk Reduction
July 2020. 1st Edition:
"Climate change is one of the greatest challenges of our time and its adverse impacts undermine the ability of all countries to achieve sustainable development. Increases in global temperature, sea level rise, ocean acidification and other climate change impacts are seriously affecting coastal areas and low-lying coastal countries, including many least developed countries and small island developing States.
SDG 11: Strengthen efforts to protect and safeguard the world's cultural and natural heritage.
COP27 2022:
Cultural heritage communities do not want to be defined by loss and damage. As cultural heritage communities are on the frontlines of climate change, the development and implementation of climate action must include them through the process in ways that enable agency, dignity, and empowerment. Waves of disaster are leaving communities with long region.

Introduction

cultural heritage can stimulate tourism, which benefits local economies, educates people with culture and history, and enhances social inclusiveness.
While the importance of preserving cultural heritage is obvious, people are facing difficulties in the preservation process. So, what can AI and other modern technologies actually do in the process of preserving cultural heritages. Artificial intelligence (AI) based automation is the emerging technology for the conservation and preservation of heritage. The application of AI in heritage conservation is divided into four clusters, (i) AI for visual inspection and structural health monitoring, (ii) AI for digital modeling, (iii) AI for intangible heritage, and (iv) AI for cultural heritage.

Affection of rising sea levele

Mediuem affected regions

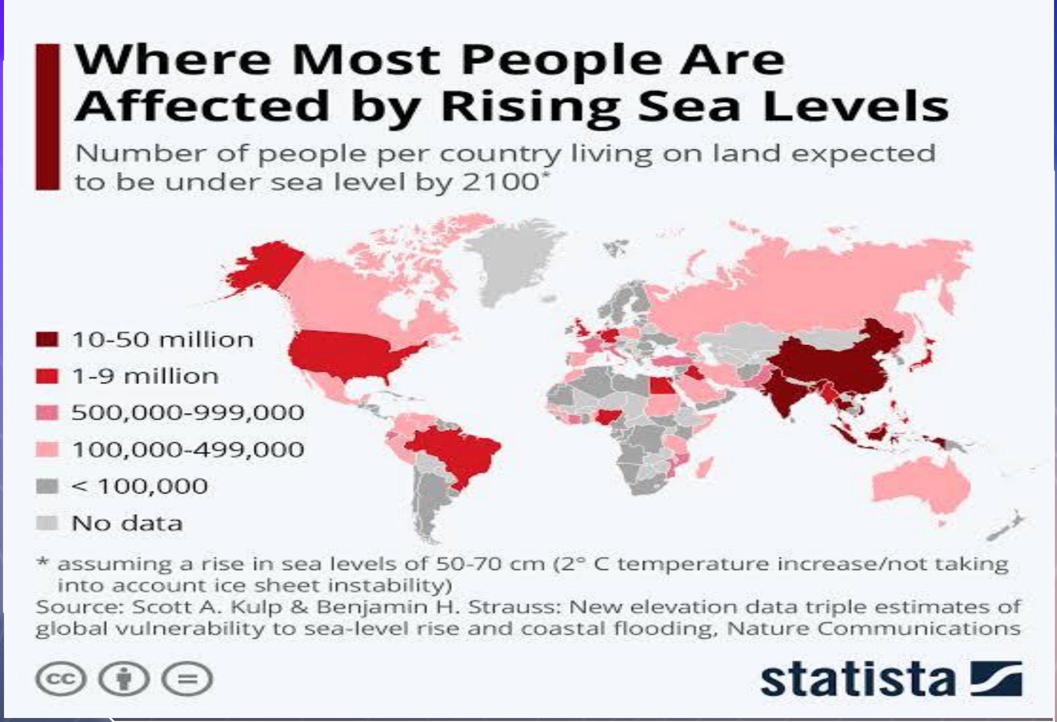
A

Most affected regions

B

Low affected regions

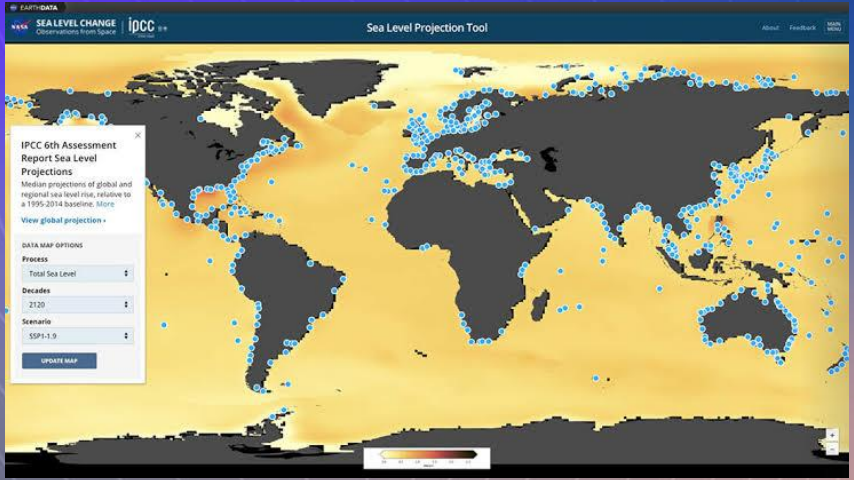
C



Predicting of sea level rise with GIS and AI

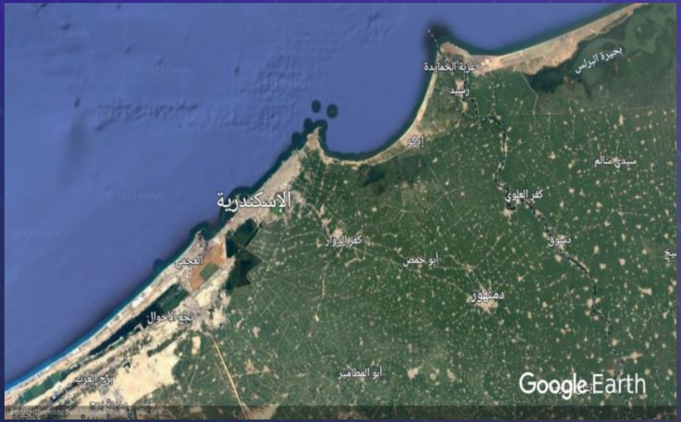
Scientists are certain the oceans will rise up. But they’re unsure when, and by how much. Artificial intelligence could help inform the picture.

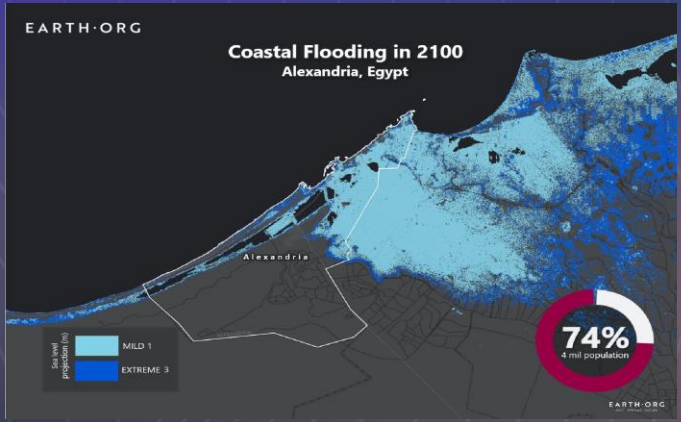
In June and July 2019, unusually warm air settled over Greenland’s ice cap—yielding near-viral footage of a dramatic melting event. Suddenly the whole world was paying attention.
Scientists know that melting ice caps—such as the one covering Greenland—will impact coastal cities sometime this century, but are less certain on when it will happen, and how much.



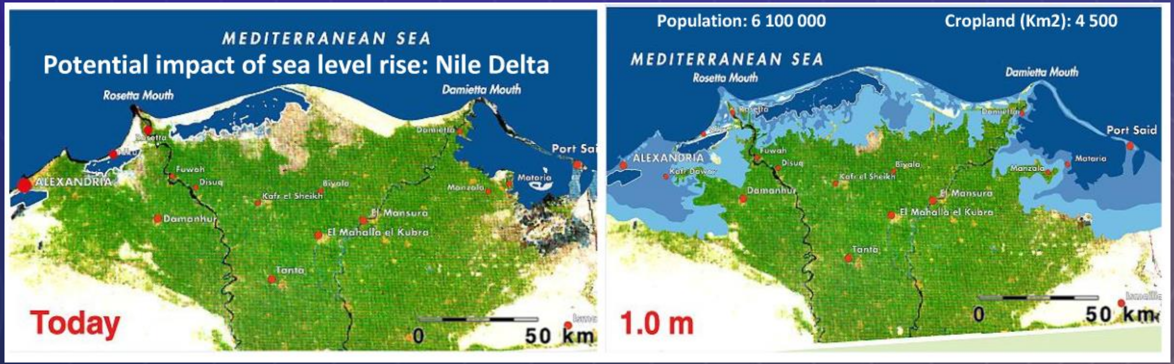
For instance Alexandria is one of the Mediterranean world heritage sites at risk from coastal flooding and erosion due to sea-level rise. The city’s position on the Mediterranean coast means it is especially vulnerable to rising sea levels. Alexandria is one of archaeological sites in Egypt at risk from flooding. All the archaeological sites in the northern coast of Egypt are also said to be at risk from coastal erosion. The flood risk in Alexandria is expected to reach a tipping point by 2050.

Alexandria , Egypt
2023





A comprehensive program has been underway since 1970 to gather data related to coastal erosion along the Nile Delta shore. Review of major coastal problems and general description of the recommended protective measures to address these problems are in the coastal Master Plan for Phase I, as Plans are underway to prepare Master Plan Phase II for coastal protection of the Nile Delta coast that will further address future climate change impacts and the need for adaptation alternatives.



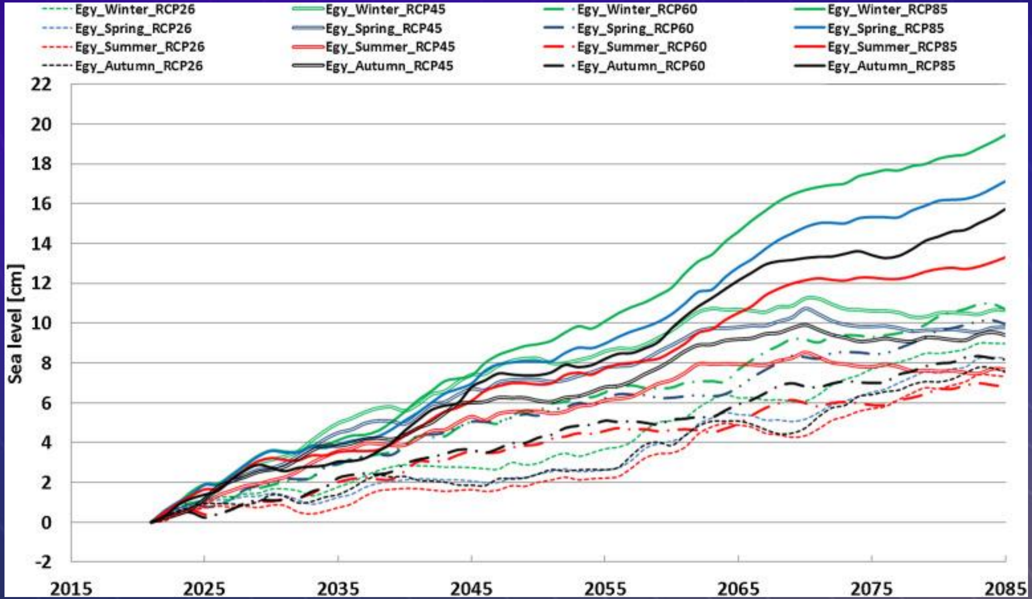


Figure seventy -year running annual mean sea levels for different seasons and emission scenarios relative to the 2015–2085 period for the GFDL-2ENM simulation.

ALEXANDRIA under different scenarios of sea level rise as shown in this figure.

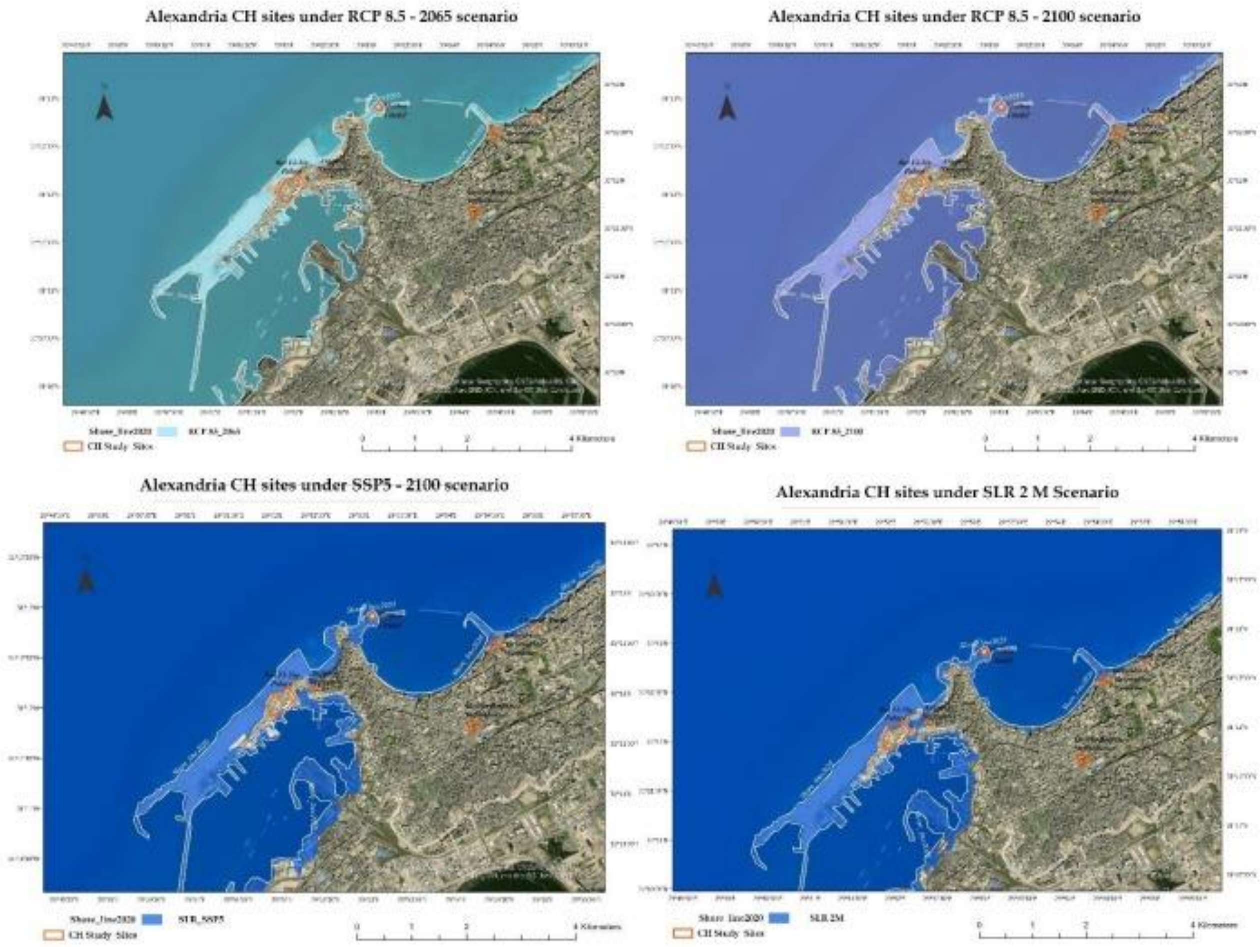
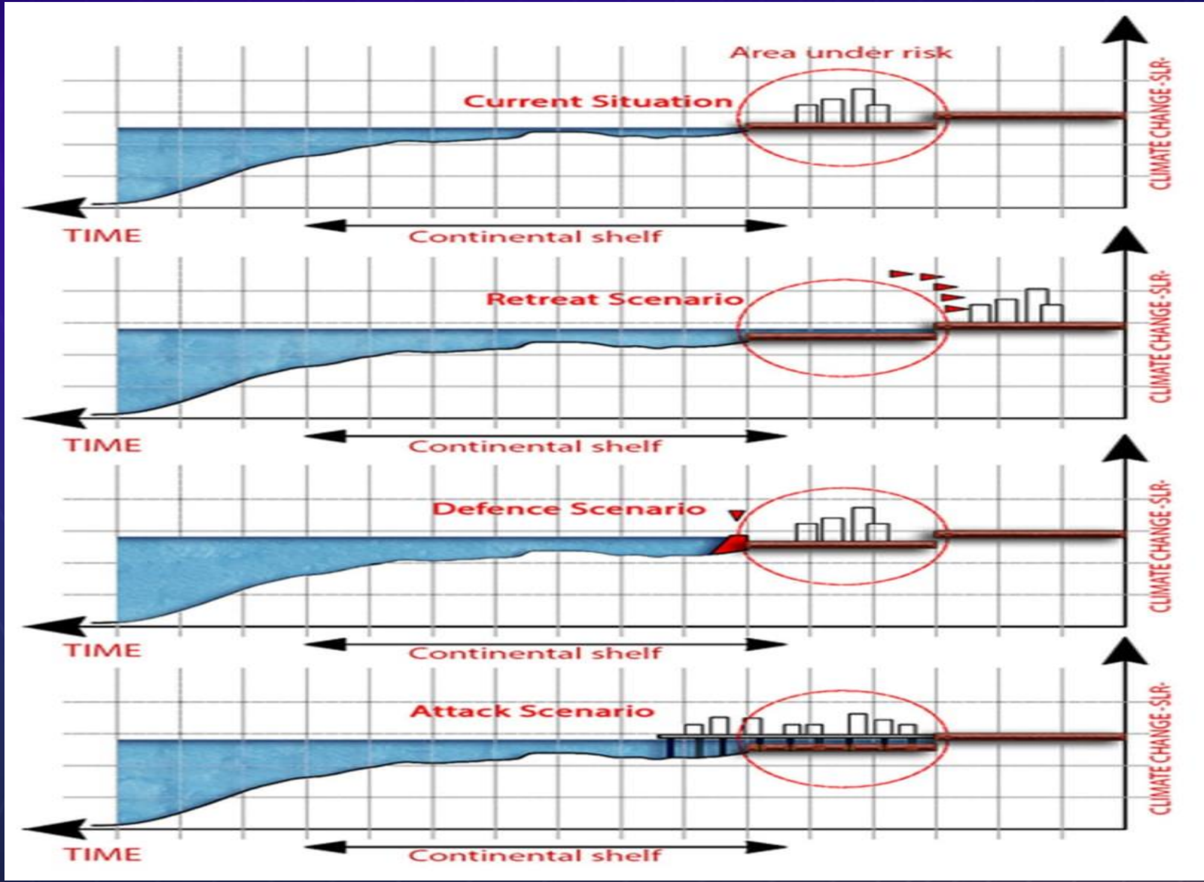
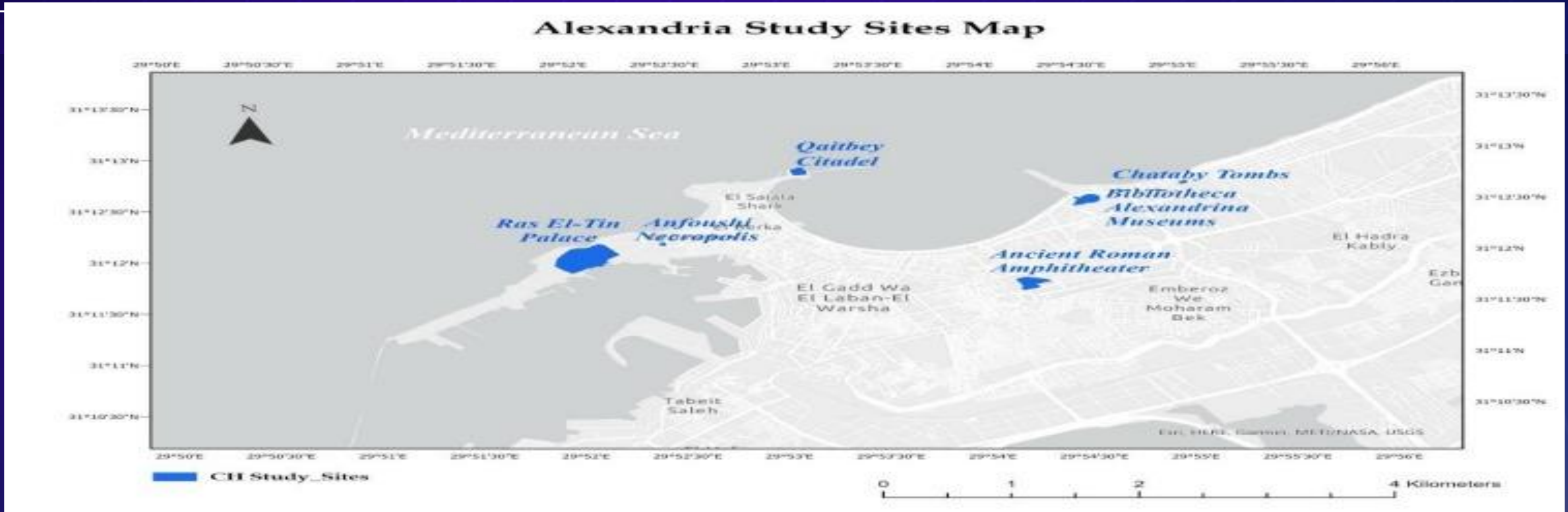


Figure CHS study areas under different SLR scenarios



Area under risk
Current Situation
CLIMATE CHANGE -SLR-
TIME
Continental shelf
Retreat Scenario
CLIMATE CHANGE -SLR-
TIME
Continental shelf
Defence Scenario
CLIMATE CHANGE -SLR-
TIME
Continental shelf
Attack Scenario
CLIMATE CHANGE -SLR-
TIME
Continental shelf



Name of archaeological site	Information about the site
Chatby Tombs	The Chatby Necropolis lies in the ancient eastern quarter, which was accidentally rediscovered in 1893.
Anfoushy Necropolis	Anfushy Necropolis is situated at the west of the eastern harbor, where five Greek graves were found in the early 20th century.
The Citadel of Qaitbay	The Citadel of Qaitbay is One of the most significant historic military buildings. It is a 15th-century defensive fortress located on the Mediterranean Sea coast, in Alexandria.
Ras El Tin Palace	Mohamed Ali Pasha constructed the Palace in 1834 to serve as a second governing headquarters.
Bibliotheca Alexandrina Museums	The Bibliotheca Alexandrina is a large library and cultural centre in Alexandria, Egypt, on the Mediterranean Sea's coast.

Keywords: Cultural Heritage Sites (CHS) , Climate Change, Sea level rise (SLR), Representative Concentration Pathways (RCPs), shared socioeconomic pathways (SSP), Coastal flooding, Coastal Erosion and Alexandria

Table CHS under SLR according to RCP 8.5.

Site Name	Distance from sea(m)	RCP 85_2065		RCP 8.5_2100	
		Flood area (Sq2)	Ratio	Flood area (Sq2)	Ratio
Qaitbey Citadel	25	2874.2	21 %	2874.21	21%
Ras El-Tin Palace	180	915.9	0.5 %	916	0.6 %
BA- Antiquities Museum	140	0	0	0	0
Chataby Tombs	117	0	0	0	0
Anfoushi Necropolis	300	0	0	0	0

As shown below the flood area ranges from 0.05% of the total WHS at Archaeological Site of Ras El-Tin Palace to 21 % at Qaitbay Citadel. therefore, the most vulnerable site is Qaitbey Citadel that will lost about 21 % of its total area if the SLR risen to 30 cm. while the other site is still safe according the two mentioned scenarios. Moreover here is flooding map for the site under these scenarios as shown

Table CHS under SLR according to RCP SSP5 AND SLR 2 m

Site Name	Distance from sea(m)	SSP5_2100		SLR_2m	
		Flood area	Ratio	Flood area (Sq2)	ratio
Qaitbey Citadel	25	5204.5	37%	6186	**44%**
Ras El-Tin Palace	180	6677.0	4%	22681	14%
BA- Antiquities Museum	140	6849.7	25%	8291	**30%**
Chataby Tombs	117	130.1	4%	286	8%
Anfoushi Necropolis	300	234.1	8%	604.352	**22%**

While under SSP Scenario the research finds that the flooded area ranges from 4% of the total of CHS at of Chatby tombs and Ras el-tin palace to 37 % at Qaitbey Citadel. Moreover, SLR 2m indicates that the most vulnerable and flooded CHS is Qaitbey Citadel with 44 % of its total areas will be exposed to flooding risk and the less sensitive site will be Cahatby tombs with 8% flooded area as shown

For example the protection of Qaitbay Citadel mission in Alexandria in the same old site of ancient Alexandria light house, they used concrete blocks of about 20 tons. other concrete The blocks were added in a wide circle to act as two lines of defense.

This solution was depends on pouring huge blocks of concrete to prevent sea water from reaching the walls .

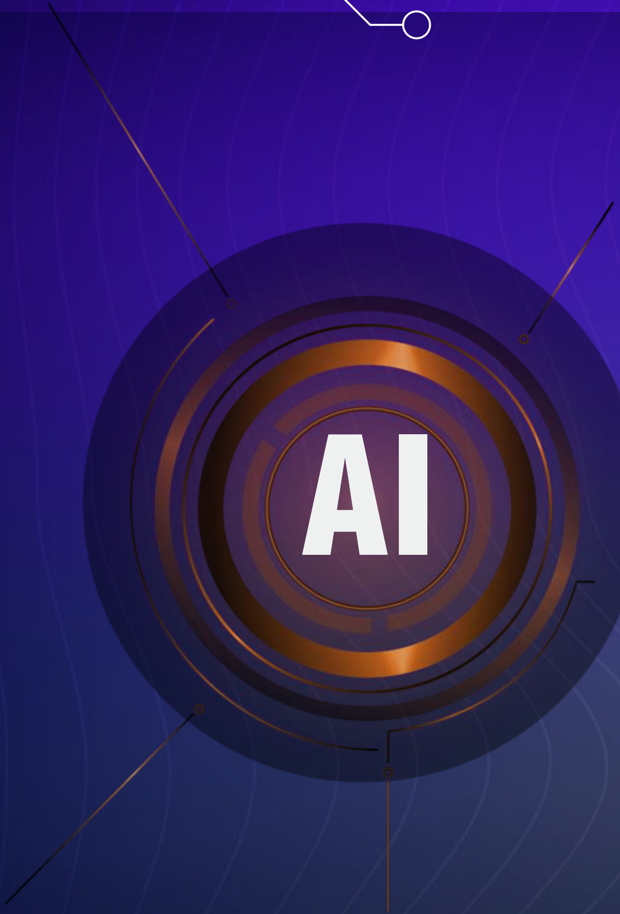
In addition to breaking waves, which causes damage to the materials. this

Not only was the solution implemented in the area directly connected to the historical site, but it was implemented.

It was also implemented in a wider circle around the site to additionally control the water level To prevent any potential waves, and provide double protection.

Figure Narrow scope of the Citadel of Qaitbay which shows the masses around it.

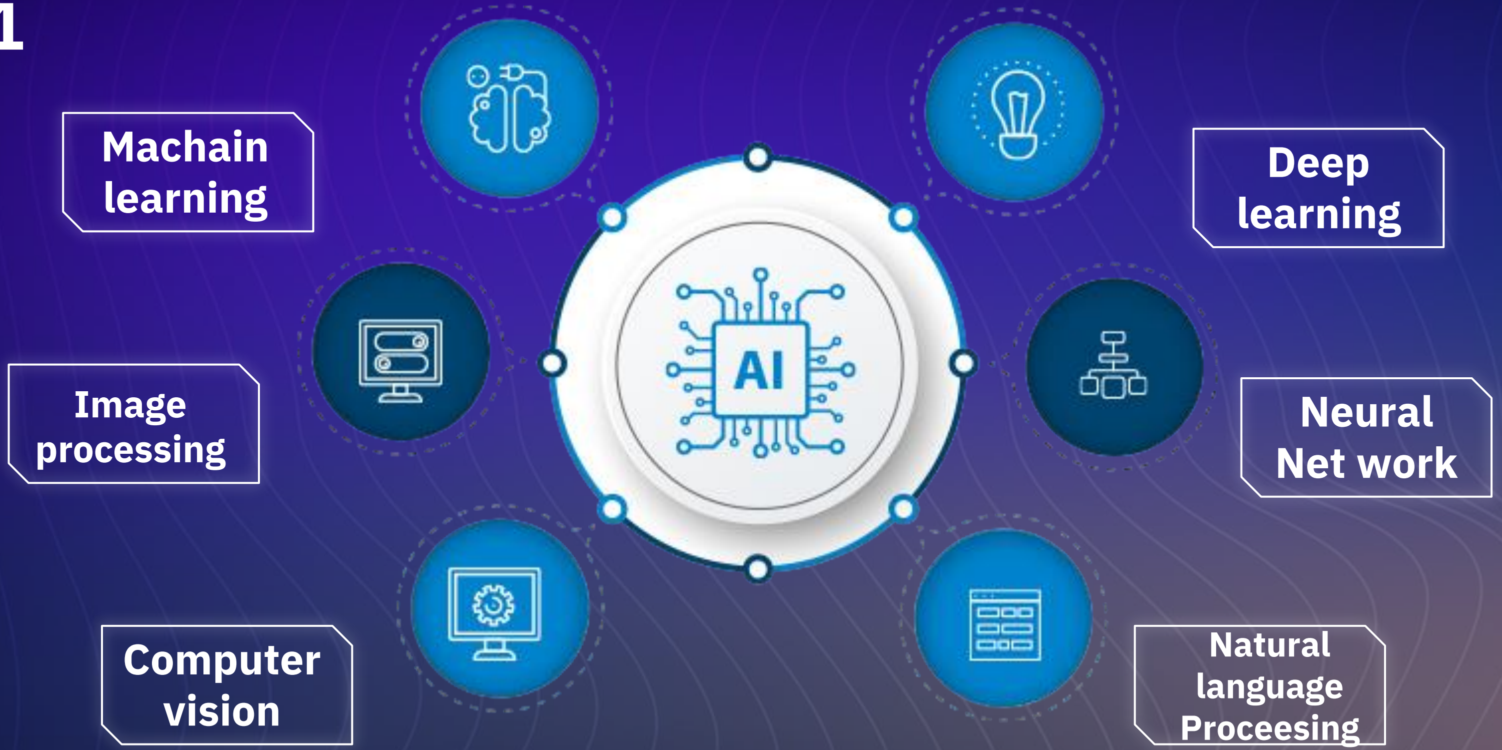
What is the AI ?
How we can use it ?



AI stands for Artificial Intelligence, which refers to the development of computer systems that can perform tasks that normally require human intelligence, such as visual perception, speech recognition, decision-making, computer vision, image processing, machine learning, deep learning, pattern recognition and language translation.

AI involves the use of algorithms and statistical models to analyze and learn from data, and to make predictions and decisions based on that analysis. There are various types of AI, including rule-based systems, machine learning, deep learning , and natural language processing, among others. AI has many applications in various fields, including conservation , restoration of monuments , antiquities and heritage sites .

1


Machain learning
Deep learning
AI
Image processing
Neural Net work
Computer vision
Natural language Proceesing

How AI works ?

Input Data

Speech -Text - Image - context- out comes

Outcome

Sucsess - Flair

Assessment

Analyses – Discovery – Feed back

Data Processing

Interpret – Predict - Act

Adjustment

Data – Algorthims - Rules

How can we use AI ?

Goals of using AI in restoration and conservation of coastal heritage

Goals of using AI in restoration and conservation of coastal heritage

Enhanced Monitoring

AI can be used to monitor and analyze changes in coastal ecosystems and heritage sites in real-time. This can help in early detection of threats and enable quick response to prevent further damage.

Predictive Analytics

AI can help analyze large amounts of data to identify patterns and predict future changes and threats to coastal heritage. This can enable proactive planning and management of coastal ecosystems to ensure their long-term sustainability.

Decision Support

AI can provide decision support tools to help conservationists and restoration experts make informed decisions about the management and restoration of coastal heritage sites. This can help prioritize conservation efforts and ensure effective use of resources.

Restoration Planning

AI can be used to create models for restoration planning and design. This can help optimize the restoration process, reduce costs, and ensure the best possible outcomes for the conservation of coastal heritage.

Goals of using AI in restoration and conservation of coastal heritage

Public Education

AI-powered tools can be used to create immersive educational experiences that help raise awareness about the importance of coastal heritage and the need for conservation and restoration efforts.

This can help engage and inspire the public to become advocates for conservation and restoration of coastal ecosystems and heritage sites.

The role of AI in shaping the future of coastal heritage

Methods of heritage conservation and management

The analysis of remote sensing data. For example, satellite and drone photogrammetry imagery can be used to capture high-resolution images of coastal areas the analysis of remote sensing data. For example, satellite and drone imagery can be used to capture high-resolution images of coastal areas

predictive models that can help identify areas at high risk of damage in the future. By analyzing historical data on coastal erosion, sea level rise, and storm surge patterns, AI algorithms can predict future changes in coastal landscapes and identify areas at risk of damage to heritage sites. This information can be used to inform conservation and management strategies, such as the relocation of at-risk heritage sites or the implementation of coastal defenses.

AI can also be used to improve the interpretation and presentation of coastal heritage sites. For example, AI-powered virtual reality experiences can provide immersive and interactive tours of heritage sites

Photogrammetry imagery

Documentation by photometric camera

- A digital camera is used to capture photos and record videos of the historical sites and buildings effectively and clearly.
- They are transferred very quickly and easily everywhere in the world.
- They are used directly in defining and processing the historical sites or enrolling them in the database.

Photogrammetry imagery

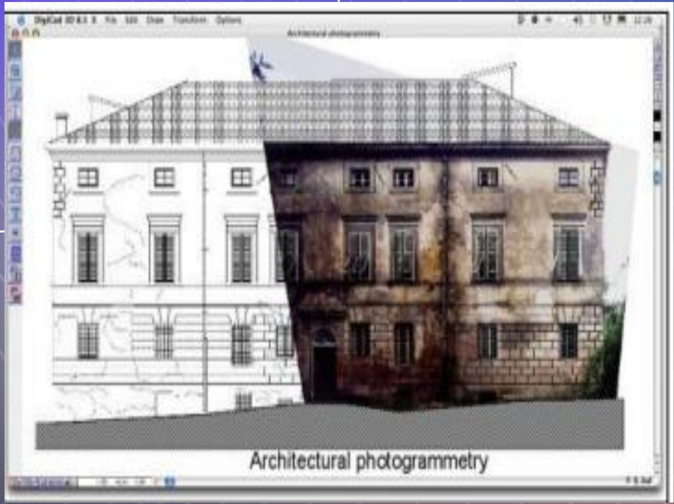
Documentation by photometric camera

- They could be stored using the modern techniques as DVD.
- This device has a great importance because of its accuracy in documentation and the easiness and
- quickness in implementation that combines between the
- photographic and metric documentation at the same time.

Photogrammetry imagery

Documentation 3D programs

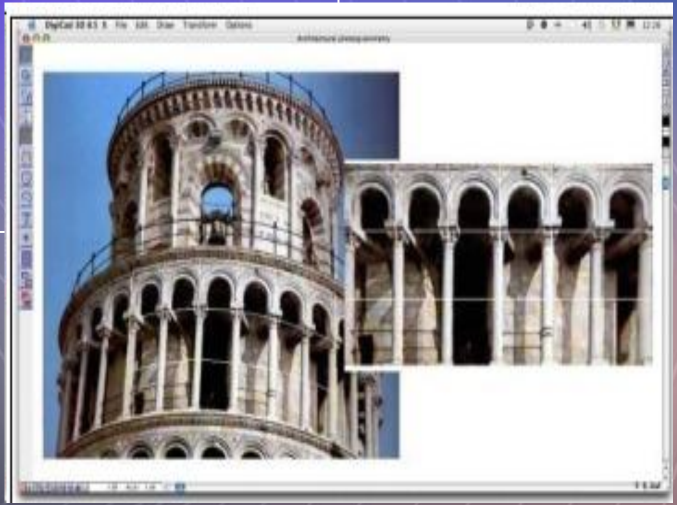
DigiCad 3D has been completely rewritten with advanced multiplatform software technologies. We invite you to download a trial version, using the program freely for 15 days.
To use the program an activation code is required, users already have it and it is not necessary to re-enter it. For the trial of the program, the request must be made through the download area and the instructions for the trial are sent automatically to the registered address.



Photogrammetry imagery

Documentation 3D programs

DigiCad 3D is an excellent tool for dealing with images, drawings, photographs of building, regular or irregular surfaces and maps. It operates either directly on raster images or by digitization. It is used in aerial and architectural photogrammetry, cartography, and mapping, for which it offers powerful, easy-to-use and exclusive instruments.



Photogrammetry imagery

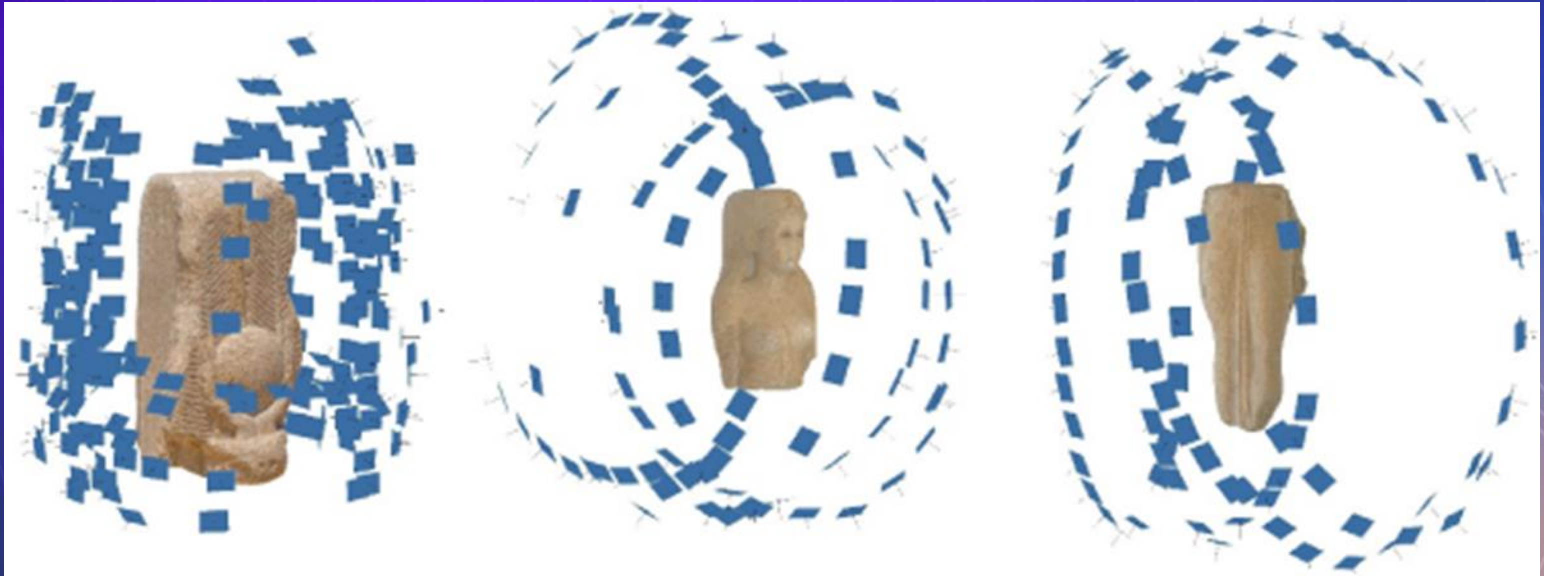


Figure presenting Camera positions during the photogrammetry of the colossal statue of Isis

Photogrammetry imagery

Figure presenting Virtual Anastylosis of the three main fragment of the colossal statue of Isis

Analyzing heritage images by AI

Object Recognition:
AI algorithms can be trained to recognize specific objects or features in images of heritage sites, such as statues, architectural details, or artwork. This can help to identify areas that require restoration or repair.

Condition Assessment:
AI can be used to analyze images of heritage sites and assess their condition. This can help experts to identify areas of deterioration, damage, or wear and prioritize restoration efforts.

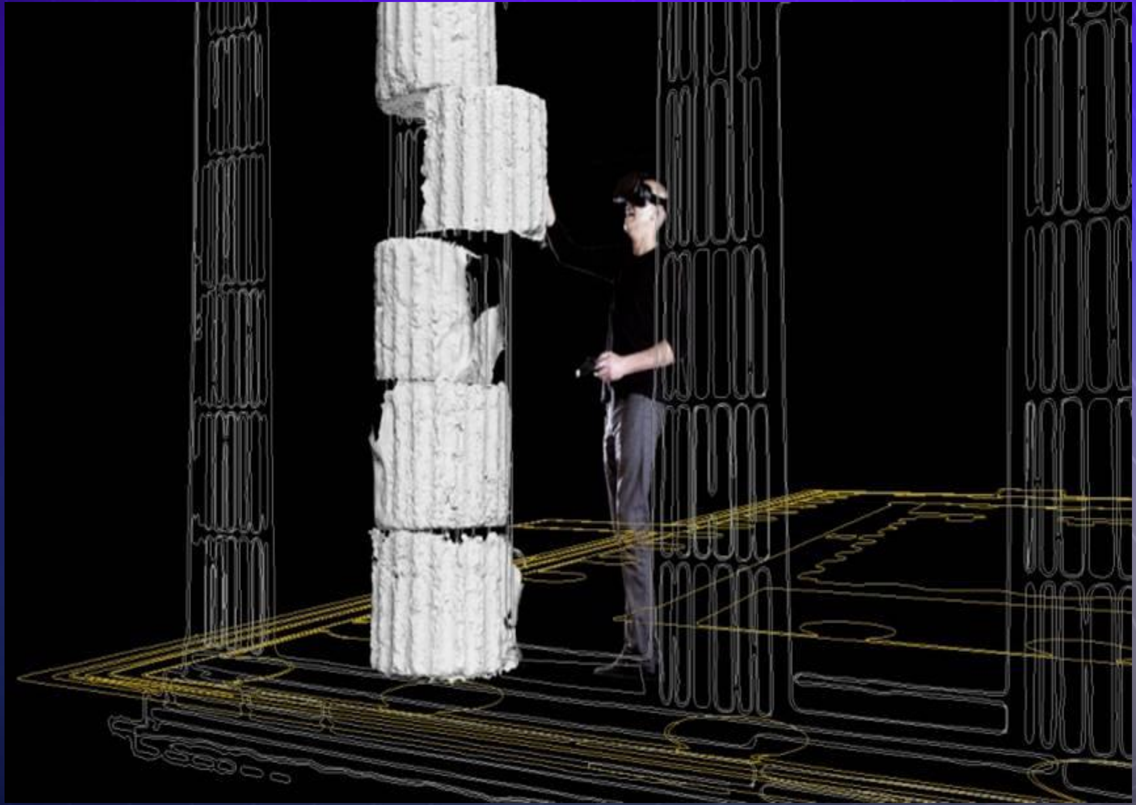
Image Restoration:
AI can be used to restore damaged or deteriorated images of heritage sites, such as photographs or paintings. This involves training algorithms to recognize the original features of the image and remove any defects or damage.

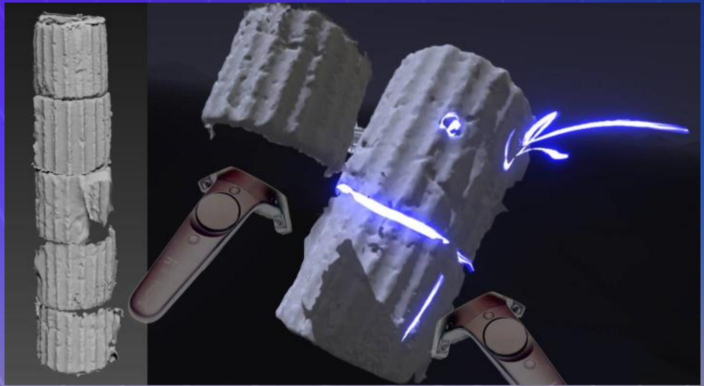
3D Reconstruction:
AI can be used to create 3D models of heritage sites from images and other data sources. This can help to visualize the site in detail and plan restoration efforts more effectively.

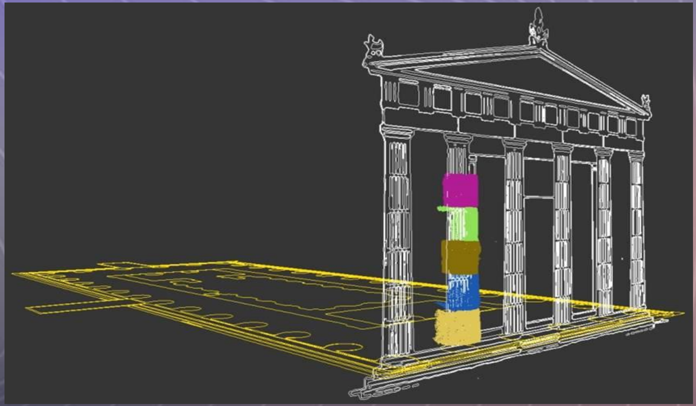
Evidence based virtual restoration

Semantic evolution of virtual restoration Virtual restoration, also known as simulation restoration or digital restoration, is based on the multilevel information of architectural heritage (such as images, point clouds, and documents), combined with traditional architectural conservation science and technology, and environmental protection, architecture, mineralogy and petrology, computer information technology, etc., and closely related to social disciplines including museology, library science, archives, archaeology, etc. Its evolution has involved three stages: virtual archaeology, virtual heritage, and digital restoration.

Evidence based virtual restoration







Documentation using 3D Laser Scanning

Documentation 3D systems

This is the most accurate technique in addition to its ability to document decorations and places that are hard to reach. This technique depends on a device that forms a data cloud. This cloud consists of small particles when they hit the buildings parts they record the coordinates XYZ. By using certain computer software, the coordinates are read and a full drawing of the building from inside and outside is performed.

Documentation using 3D Laser Scanning

Documentation 3D systems

The RTC360 combines high-performance laser scanning, edge computing and mobile app technologies to pre-register captured scans quickly and accurately. With the push of a button, two million points per second of High Dynamic Range (HDR) imagery can be captured to create a full-dome scan in under two minutes. Laser scanner movements between setup positions are automatically tracked by a Visual Inertial System (VIS) while scans are combined and pre-registered on a mobile device, where they can be viewed and augmented with information tags – saving precious time and speeding up decision-making right from the field.

Documentation of Case study: Citadel of Qaitbay in Alexandria

01

AUTO CAD

AUTODESK AutoCAD

2D

02

PHOTO SHOP

Ps

IMAGE

03

3D MAX

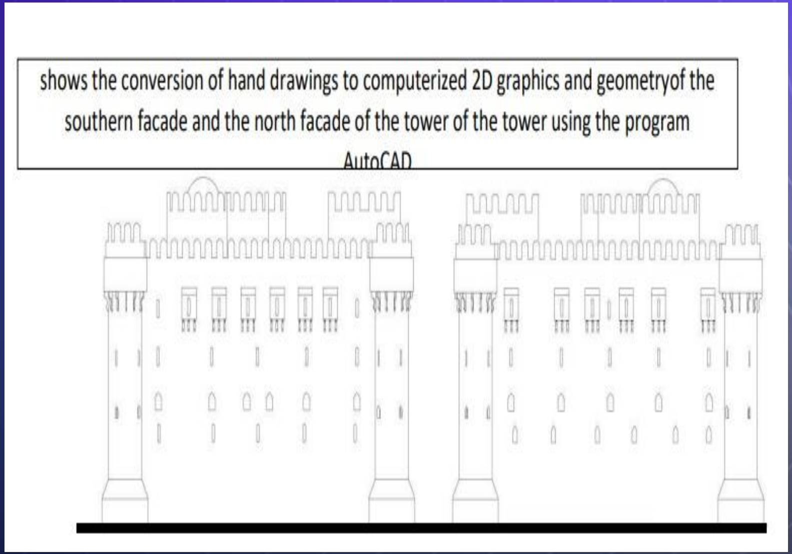
3 MAX

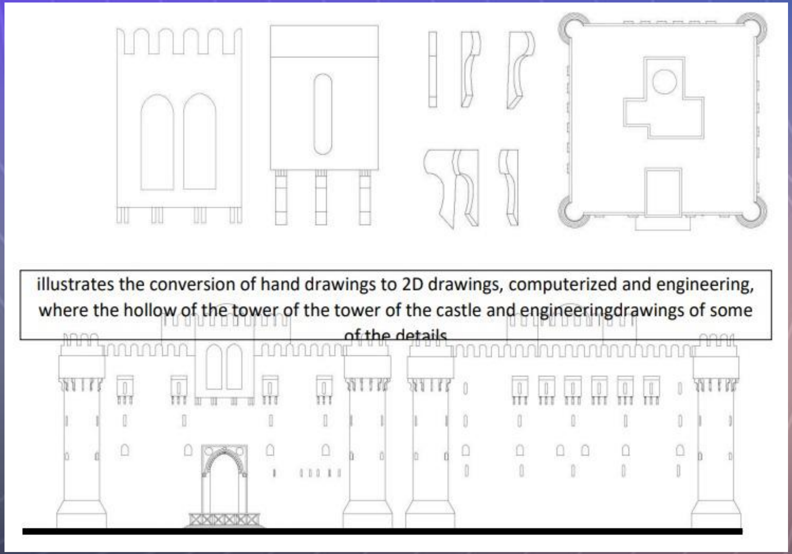
AUTODESK 3ds Max 2023

3D

Documentation by using AutoCAD

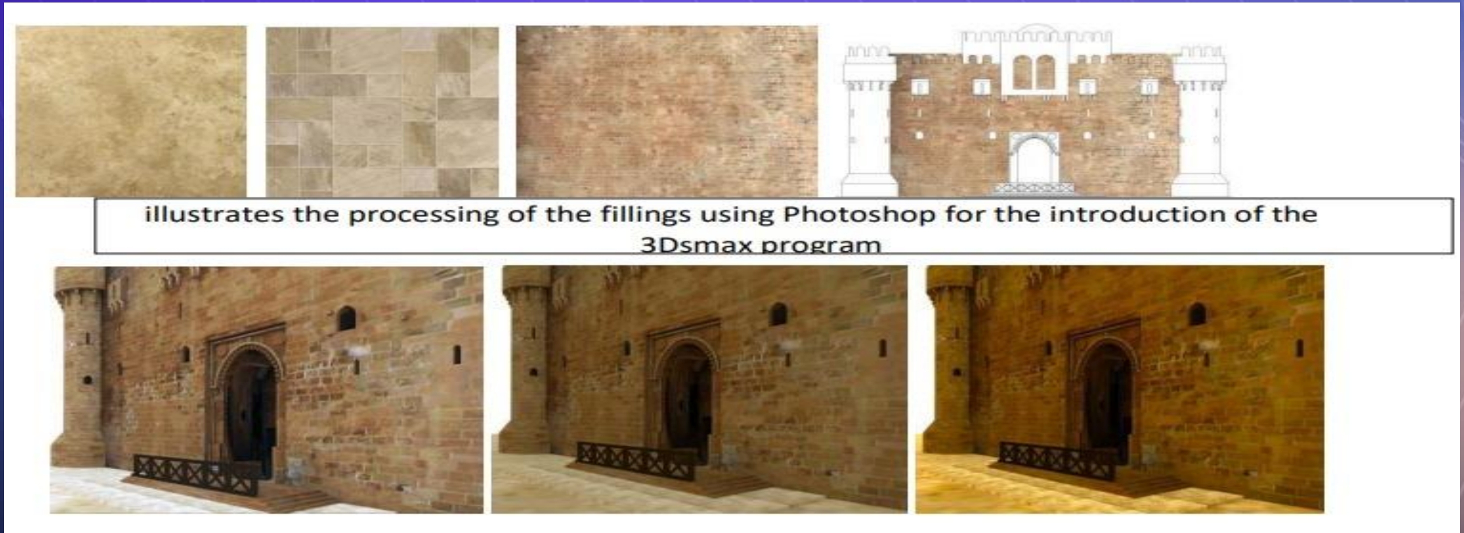
AutoCAD is a sketching and designing software. It support creating 2D and 3D drawings. In this phase, the manual drawings and sketches into 2D. In thecase of having 2D pictures of some parts of the building, (tracing) could be used using the Photogrammetric drawing.





Documentation by using Adobe Photoshop

This software is used in image processing and preparing textures to be used in the 3Ds Max. The software could serve in the transformation of the 2D pictures in case of unavailability of Photogrammetric. Thus, tracing could be done by AutoCAD



Documentation by using 3D Max

In this phase, the drawings and 2D plans are transformed into 3D using 3DsMAX software or importing it from AutoCAD as it is very compatible with it. The software is used in texturing, lighting and rendering. It also export to VRML technique. It also can link some parts of the building with Hyperlink to support the virtual tour with some texts and instructions.

Documentation by using 3D Max

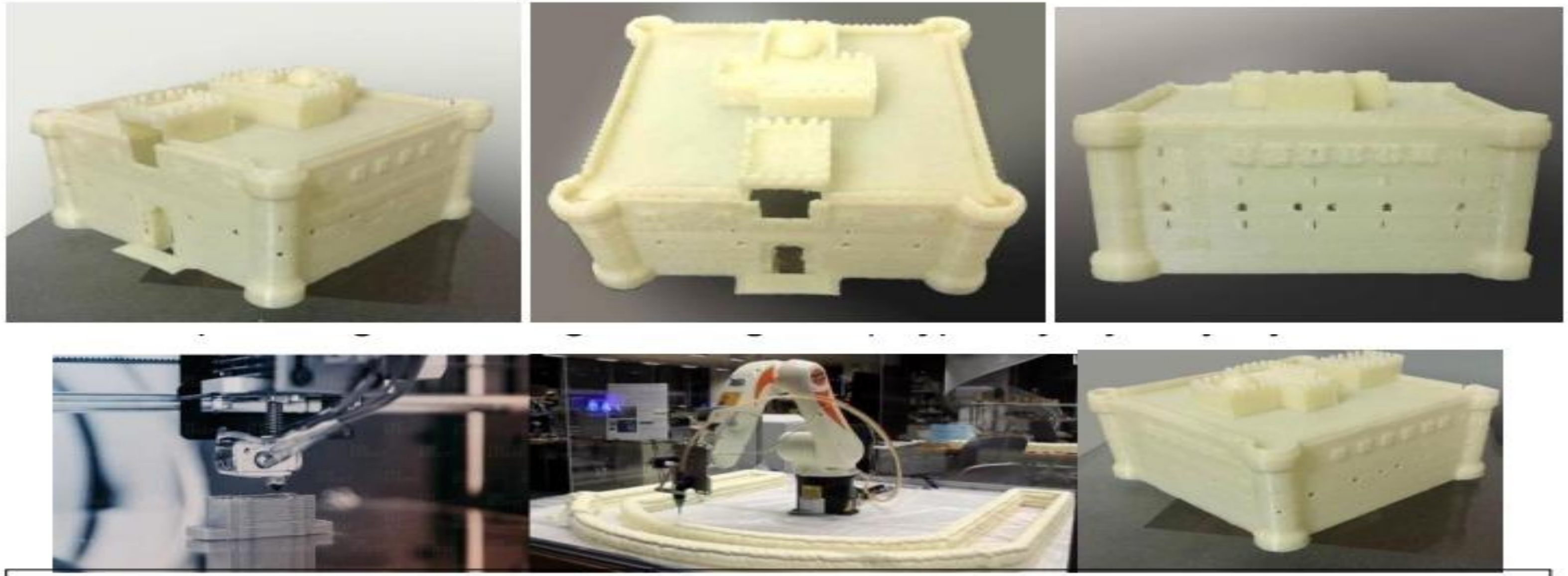
3D modeling using 3Ds MAX Program that allows Mapping & Texturing

On the right is the eastern façade and on the left the western façade of the maintower

Scenic snapshots of the main tower of the castle using 3Ds MAX Program

3d modeling using 3D Printing

3D printing is any of various processes in which material is joined or solidified under computer control to create a three dimensional object, with material being added together (such as liquid molecules or powder grains being fused together), typically layer by layer.

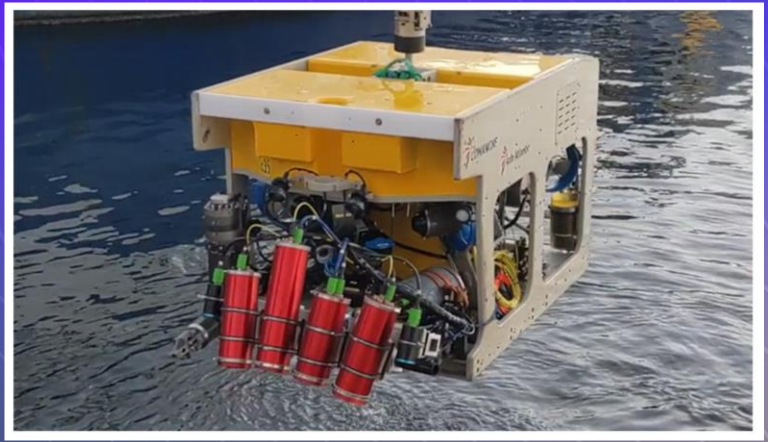


3D model of the castle using 3D printer

AI and 3D scanning under water

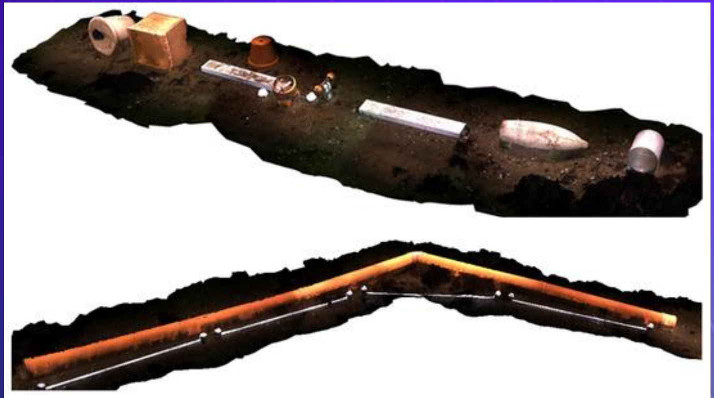
Three-dimensional capturing of underwater archeological sites or sunken shipwrecks can support important documentation purposes. In this study, a novel 3D scanning system based on structured illumination is introduced, which supports cultural heritage documentation and measurement tasks in underwater environments. The newly developed system consists of two monochrome measurement cameras, a projection unit that produces aperiodic sinusoidal fringe patterns, two flashlights, a color camera, an inertial measurement unit (IMU), and an electronic control box. The opportunities and limitations of the measurement principles of the 3D scanning system are discussed and compared to other 3D recording methods such as laser scanning, ultrasound, and photogrammetry, in the context of underwater applications. Some possible operational scenarios concerning cultural heritage documentation are introduced and discussed. A report on application activities in water basins and offshore environments including measurement examples and results of the accuracy measurements is given. The study shows that the new 3D scanning system can be used for both the topographic documentation of underwater sites and to generate detailed true-scale 3D models including the texture and color information of objects that must remain under water.

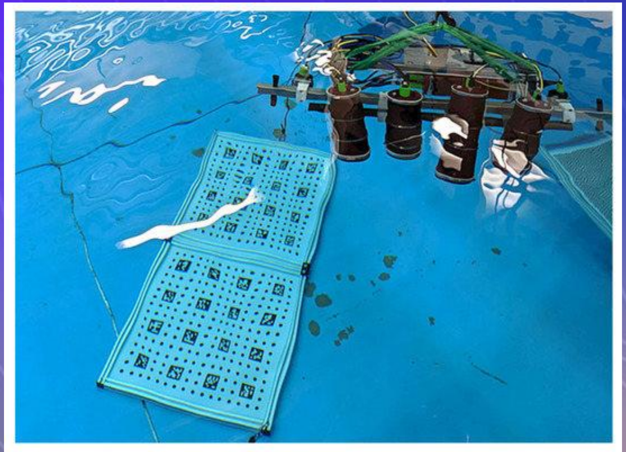
AI and 3D scanning



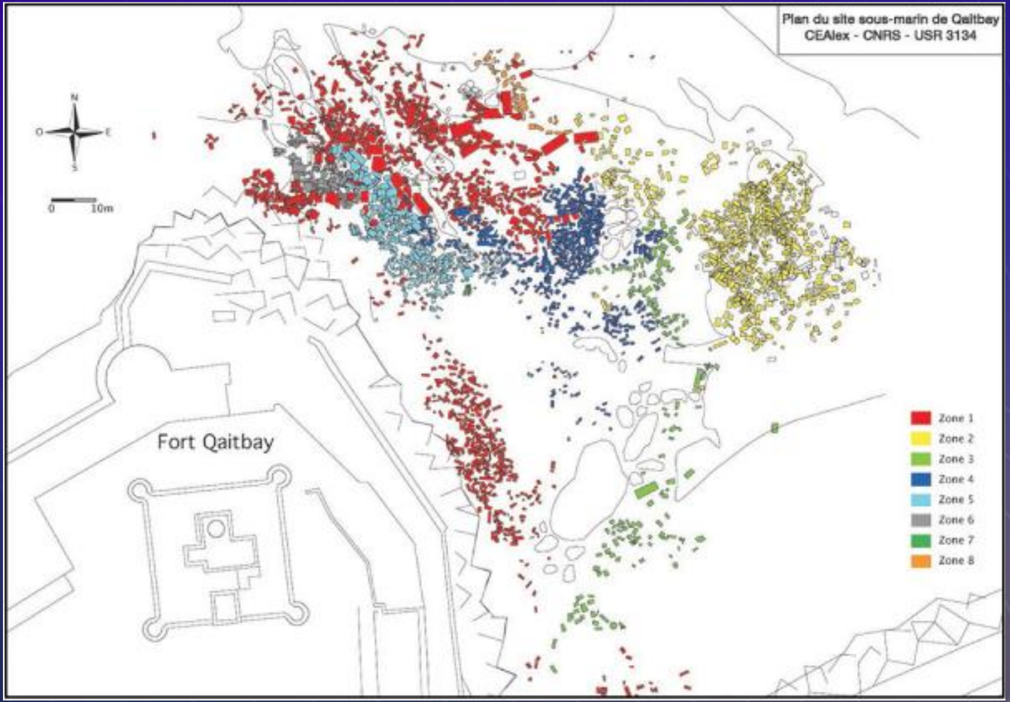
Underwater 3D Scanning System for Cultural Heritage Documentation

Underwater Cultural Heritage Documentation





A figure showing : Plan of the underwater archaeological site of Qaitbay Fort (CEAlex)



Example of Underwater Cultural Heritage Documentation

Reconstructions of palace area and lighthouse in Alexandria

Remains of Alexandria lighthouse

REMAINS OF PTOLEMAIC ALEXANDRIA

Underwater Cultural Heritage Documentation

Underwater Cultural Heritage Documentation

The documentation of submerged cultural sites and objects has two main requirements. The first demand is the generation of a map of the site and the second task is the production of detailed models of certain objects or parts of objects. The balance between these two aspects may be even or not, depending on the conditions of the specific site. Our new scanning system, for example, provides the possibility of 3D reconstruction of the whole area where the color camera, as part of the system, records images with sufficient object structure for 3D reconstruction using visual odometry . As the result of the process of simultaneous localization and mapping (SLAM), a map of a certain seafloor region will be generated and stored . Additionally, certain objects of particular interest can be scanned three-dimensionally with high detail resolution and measurement accuracy.

Example of Underwater Cultural Heritage Documentation

Reconstructions of palace area and lighthouse in Alexandria

THE RED LINE REPRSENTS THE ANCIENT COASTLINE DISCOVERED BY FRANCK GODDIO AND HIS TEAM.

Example of Underwater Cultural Heritage Documentation

Reconstructions of palace area and lighthouse in Alexandria

NO	Description
1	Granite pedestal, granite Pylon and a granite casing of large door.
2	Longated contours running parallel to the cape. here is also a line of structures parallel to the coast.
3	Foundation of large building.
4	Remains of a massive gate to the palace area.
5	Remains and foundation of the temple of Poseidon.
6	Remains and foundation of Timonium.
7	Remains of the Antirhodos Palace.
8	Remains and foundation of a temple dedicated to Isis.
9	Ionic and Doric orders of a large building. 290 BC.
10	High quality dog and wrestler mosaic. 125 -150 BC.

Example of Underwater Cultural Heritage Documentation

Reconstructions of palace area and lighthouse in Alexandria

NO	Description
11	Stag hunt mosaic from a large banqueting room. 290-260 BC.
12	Warrior mosaic, it is not clear to what type of building it belonged. 320-300 BC.
13	House/dining room with Rosette mosaic. 300-250 BC.
14	Centaur and stag mosaic in a Corinthian building. 250-225 BC.
15	Monumental Doric stoa.
16	Greco Egyptian temple dedicated to Serapis, Isis Ptolemy IV Philopator and his wife Arsinoe III.
17	Remains of Ptolemaic houses below Roman constructions.
18	The foundation of Serapium, built by Ptolemy III (reigned 246–222 BC).
19	The location of the obelisks known as Cleopatra’s Needles, that syod in front of the Caesareum.

Example of Underwater Cultural Heritage Documentation
3D reconstruction of lighthouse of Alexandria

Example of Underwater Cultural Heritage Documentation

Reconstructions of palace area

Example of Underwater Cultural Heritage Documentation

Reconstructions of palace area

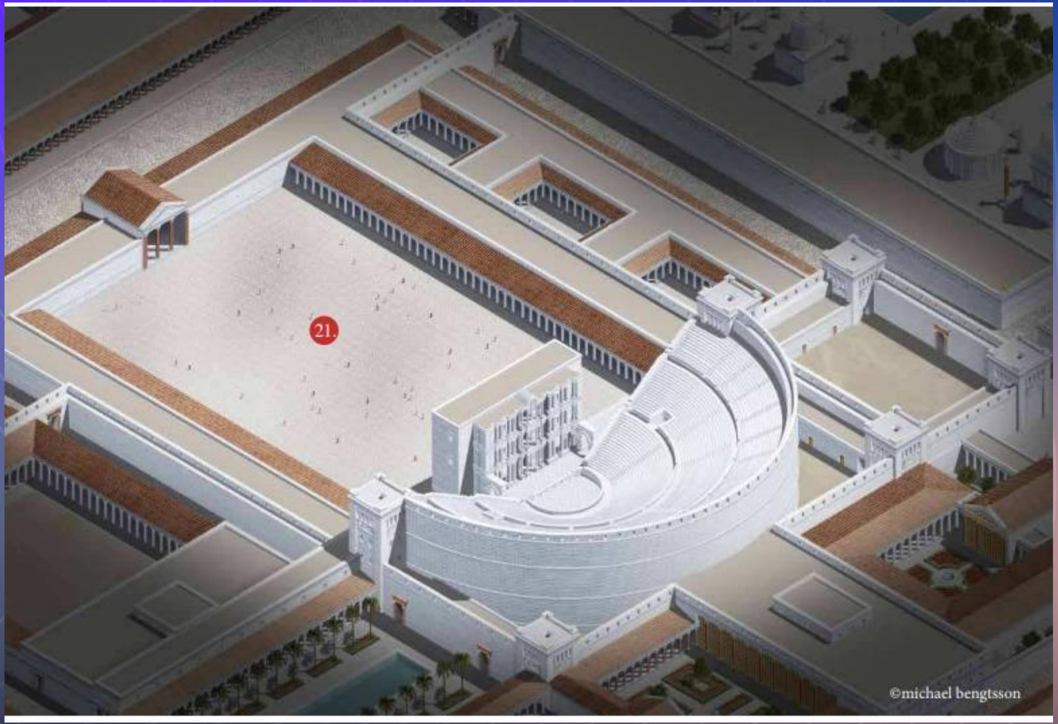
Example of Underwater Cultural Heritage Documentation

Reconstructions of Theater

THEATRE OF DIONYSUS similar of Kom el deka theater.

Strabo writes: “Above the artiicial harbor lies the theatre, then the Poseidium.

Caesar, De bello civili III: “In this quarter of the town was a wing of the king’s palace,
in which Caesar was lodged on his first arrival,
and a theater adjoining the house which
served as for a citadel, and had approaches to the port and to the rest of the dockyards.

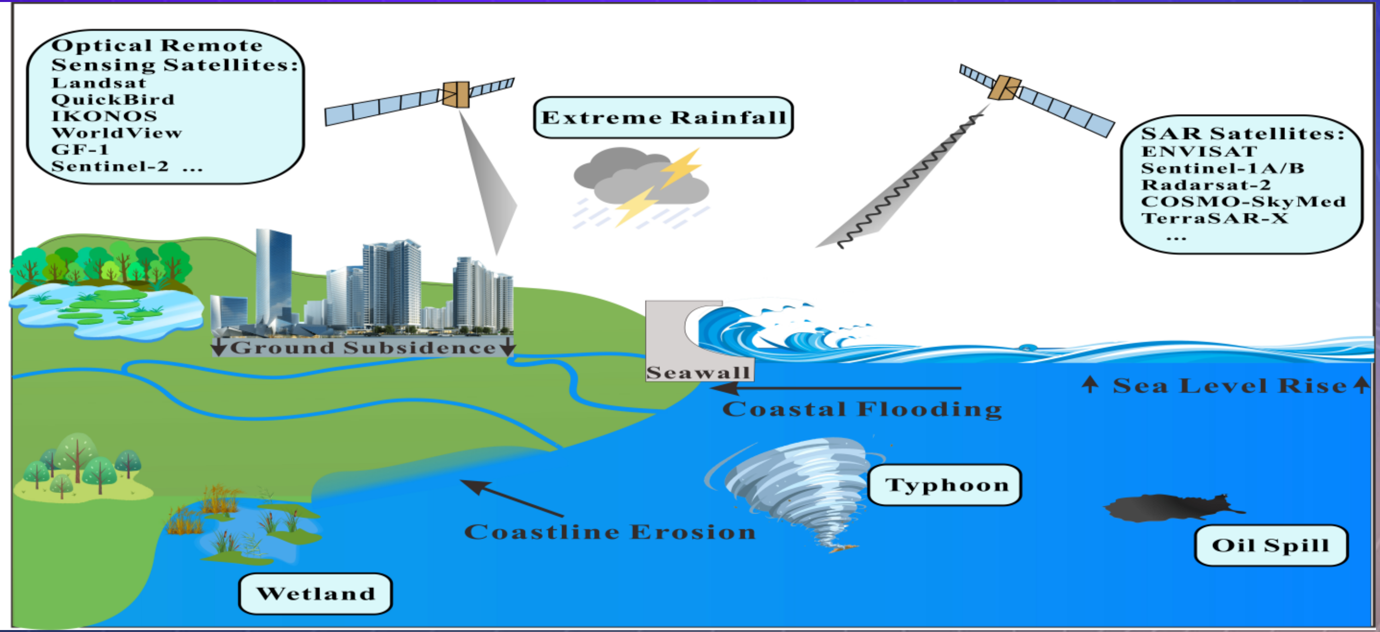


Remote sensing technologies

The documentation and protection of archaeological and cultural heritage (ACH) using remote sensing, a non-destructive tool, is increasingly popular for experts around the world, as it allows rapid searching and mapping at multiple scales, rapid analysis of multi-source data sets, and dynamic monitoring of ACH sites and their environments. The exploitation of remote sensing data and their products have seen an increased use in recent years in the fields of archaeological science and cultural heritage. Different spatial and spectral analysis datasets have been applied to distinguish archaeological remains and detect changes in the landscape over time, and, in the last decade, archaeologists have adopted more thoroughly automated object detection approaches for potential sites. These approaches included, among others, object detection methods, such as those of machine learning (ML) and deep learning (DL) algorithms, as well as convolutional neural networks (CNN) and deep learning

A Convolutional Neural Network (CNN) is a type of neural network that is primarily used for image classification

Remote sensing technologies

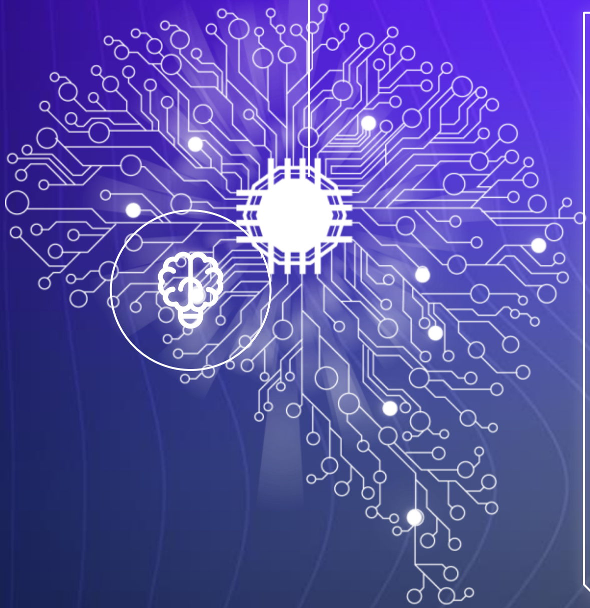


Documentation using the technique of the geographic information system

GIS

GIS is an important tool for urban planning. GIS includes software and hardware tools, and a group of procedures elaborated to facilitate the capture, edition, administration, manipulation, analysis, modeling, representation and the exit of spatial referenced and semantic data, to solve any type of planning, administration, storage, and further information concerning the problem

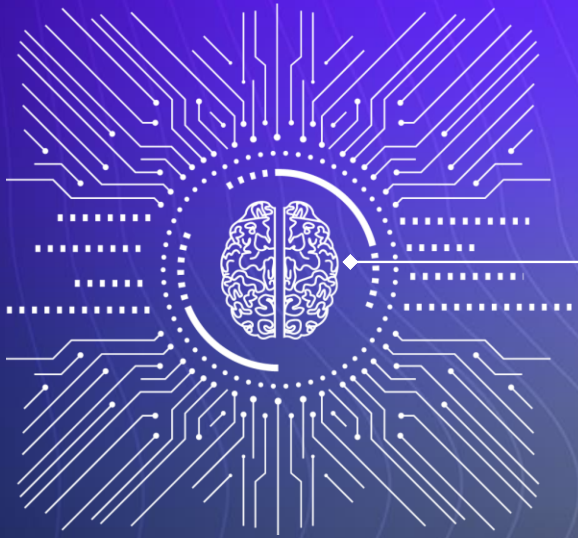
Neural networks



We can use neural networks to develop a strategy plan for conservation and restoration of coastal heritage sites, conservationists and managers can make more informed decisions about how to protect these valuable cultural and historical resources.

Neural networks are a type of machine learning algorithm that are modeled after the structure and function of the human brain. They consist of interconnected nodes (or neurons) that process and transmit information. Neural networks can be used for a variety of tasks, including image recognition, natural language processing, and predictive analytics.

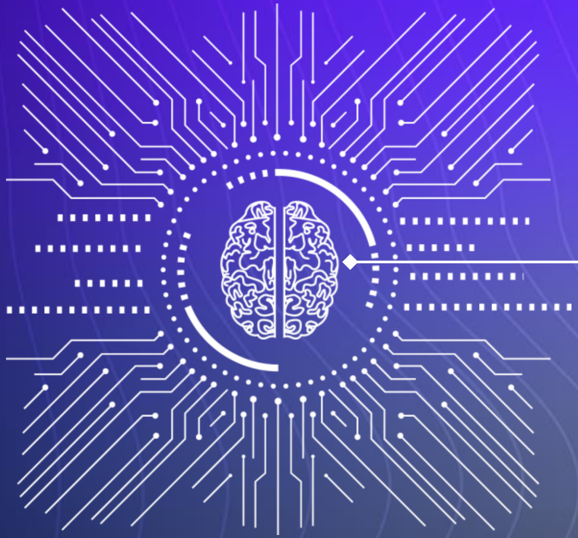
Deep learning and Machine learning



Machine learning is a subfield of artificial intelligence that involves building algorithms and models that enable computers to learn from data and make predictions or decisions without being explicitly programmed to do so.

The goal of machine learning is to create systems that can automatically improve their performance on a specific task by iteratively learning from data.

Deep learning and Machine learning



Machine Learning is the core of artificial intelligence, and deep learning is the hot research direction in the core. GeoAI includes two parts: Geospatial Machine Learning and Geospatial Deep Learning. Taking SuperMap as an example, users can solve a variety of GIS application problems such as spatial clustering, spatial classification, and spatial regression based on Geospatial Machine Learning.

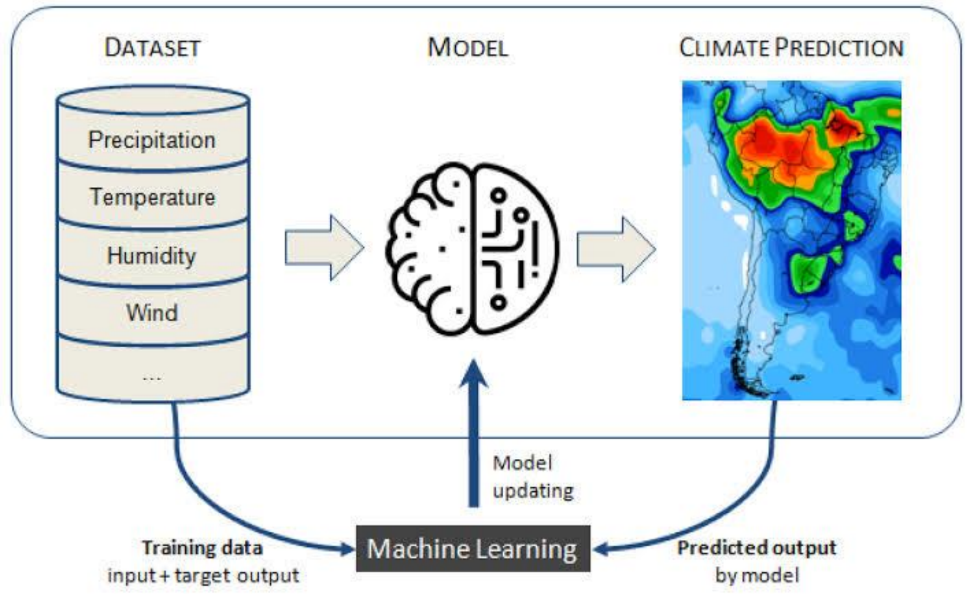
Machine learning in archaeology

Machine learning (ML) is rapidly being adopted by archaeologists interested in analyzing a range of geospatial, material cultural, archaeological materials chemical composition, textual, natural, and artistic data. The algorithms are particularly suited toward rapid identification and classification of archaeological features and objects. The results of these new studies include identification of many new sites around the world and improved classification of large archaeological datasets. ML fits well with more traditional methods used in archaeological analysis, and it remains subject to both the benefits and difficulties of those approaches. Small datasets associated with archaeological work make ML vulnerable to hidden complexity, systemic bias, and high validation costs if not managed appropriately. ML's scalability, flexibility, and rapid development, however, make it an essential part of twenty-first-century archaeological practice.

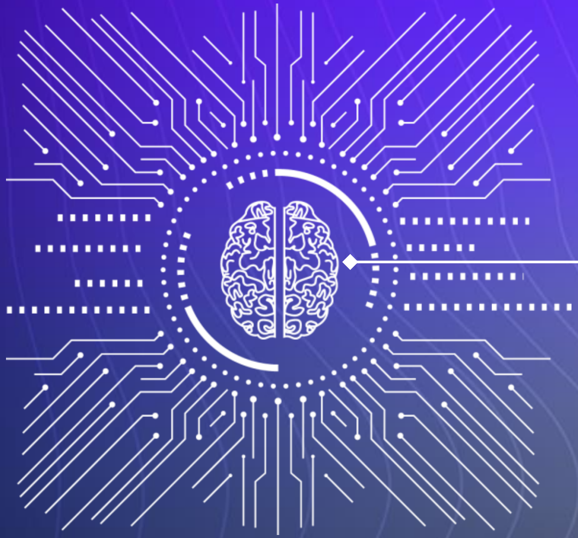
Archaeologists have broadly focused on the following types:

- Numerical and/or categorical data
- Textual data
- Images
- Geospatial data to learn from data and then make predictions from those data

The machine-learning algorithm, can help us to understand how sea-level rise impacts could unfold across a wide range of futures, and ultimately help find adaptation options more tolerant to changing projections of sea level. since we can model many potential flood impacts including direct impacts (e.g., building damage) and indirect impacts (e.g., sewage backup and disruptions to businesses, hospitals, and transportation systems). She modelled the spatial distribution of these impacts both within and beyond the area directly inundated.
So this machine-learning algorithm allows the impacts across a wide range of future scenarios to be shown as a concise set of spatial maps that are understandable by different stakeholders, so it can be a great platform to develop a shared understanding of the risk.



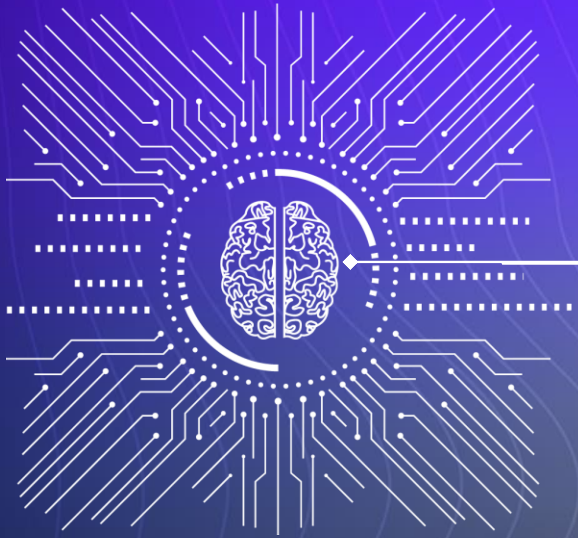
Example for using machine learning



Weka is a collection of machine learning algorithms and tools for data mining tasks developed at the University of Waikato in New Zealand. The software is open-source and is written in Java, making it platform-independent and accessible to a wide range of users.

InfraNodus is a text network analysis tool that can be used to analyze and visualize complex relationships between concepts and ideas within a body of text.

Example for using machine learning



While **InfraNodus** may not be specifically designed for conservation and preservation of coastal heritage, it could potentially be used to assist in these efforts by analyzing and organizing relevant information.

For example, **InfraNodus** could be used to analyze relevant documents and texts related to coastal heritage, including historical records, scientific research, and policy documents. By analyzing the relationships between key concepts and ideas within these texts, **InfraNodus** could help to identify important themes and insights that could inform conservation and preservation efforts.

InfraNodus could also be used to map out the relationships between different stakeholders involved in coastal heritage conservation and preservation efforts, such as government agencies, non-profit organizations, local communities, and scientific researchers. By analyzing the connections between these stakeholders**, InfraNodus** could help to identify potential areas of collaboration and areas where more outreach and engagement may be needed.

Example for using InfraNodus program

Table 3. A sample of the output files from Infra Nodus.

Node Name	Degree	Frequency	Betweenness	Topic	Conductivity	Locality	Diversity
Sum Total	648	134	2.691812	n/a	1749.7	64	8038.2
Sum/74 Nodes	8.76	1.81	0.036376	n/a	23.64	0.86	108.62
site	43	11	0.675038	2	157	0	613.7
research	16	4	0.25	0	156.3	0	625
heritage	38	9	0.221461	2	58.3	1	246.1
resilient	24	6	0.189498	0	79	0	315.8
plan	24	4	0.161752	0	67.4	0	404.4
machine	9	3	0.126712	3	140.8	0	422.4
change	23	7	0.122146	1	53.1	0	174.5
climate	25	6	0.11035	1	44.1	1	183.9
coastal	16	4	0.082572	2	51.6	0	206.4
learning	8	3	0.079909	3	99.9	0	266.4
make	11	2	0.064688	2	58.8	0	323.4
difference	6	1	0.055524	6	92.5	0	555.2
approach	11	3	0.055175	0	50.2	0	183.9
main	6	1	0.054604	6	91	0	546
hazard	11	2	0.050609	2	46	0	253
case	11	2	0.048896	4	44.5	0	244.5
adaptation	15	3	0.046423	0	30.9	0	154.7
impact	13	4	0.045282	1	34.8	0	113.2
represent	6	1	0.040049	2	66.7	0	400.5
method	10	2	0.031963	0	32	0	159.8
highlight	6	1	0.019914	6	33.2	0	199.1
data	10	2	0.019692	0	19.7	1	98.5
factor	6	1	0.018994	6	31.7	0	189.9
classifying	6	1	0.016933	6	28.2	0	169.3
range	6	1	0.016584	6	27.6	0	165.8
gathering	4	1	0.013604	3	34	0	136
general	6	1	0.013413	2	22.4	0	134.1
technique	5	1	0.013413	3	26.8	0	134.1
specific	6	1	0.012652	2	21.1	0	126.5
resilience	6	1	0.010306	6	17.2	0	103.1
algorithm	6	1	0.009957	6	16.6	0	99.6
adapt	10	2	0.009513	0	9.5	1	47.6
propose	6	1	0.001522	6	2.5	2	15.2
responsible	6	1	0.001522	6	2.5	2	15.2
renewable	6	1	0.000381	2	0.6	9	3.8
resource	6	1	0.000381	2	0.6	9	3.8
challenge	6	1	0.00019	2	0.3	19	1.9
relation	6	1	0.00019	4	0.3	19	1.9
reduce	6	1	0	1	0	0	0

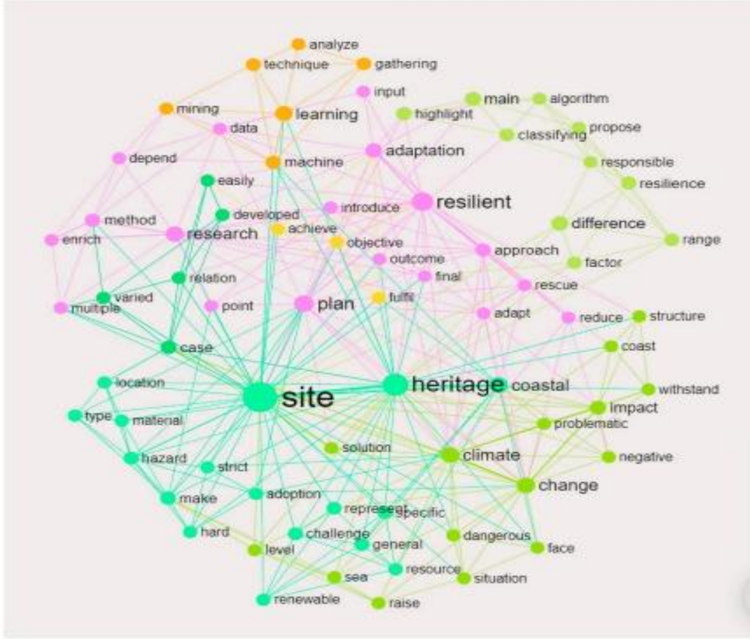
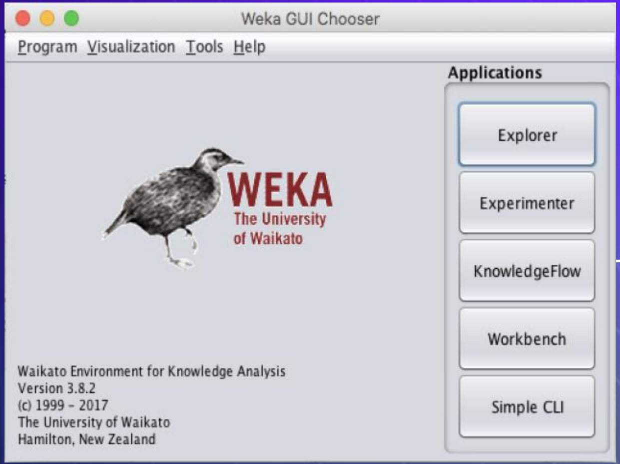


Figure The final processed cluster of information that produced the output files

Example for using WEKA program



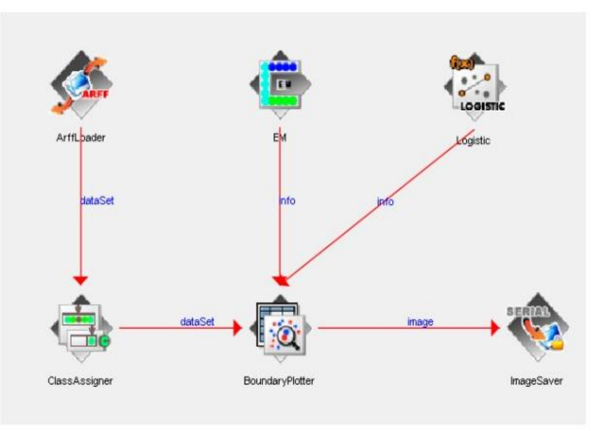


Figure Data mining visualizing prediction boundaries.

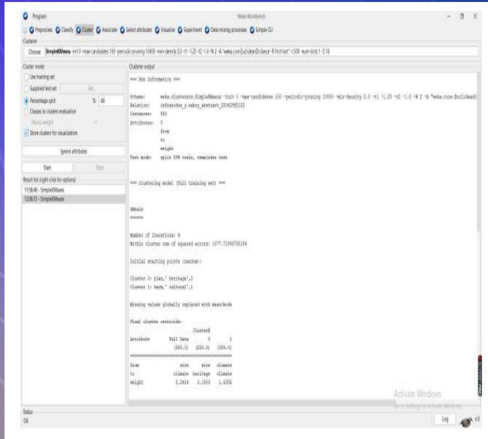
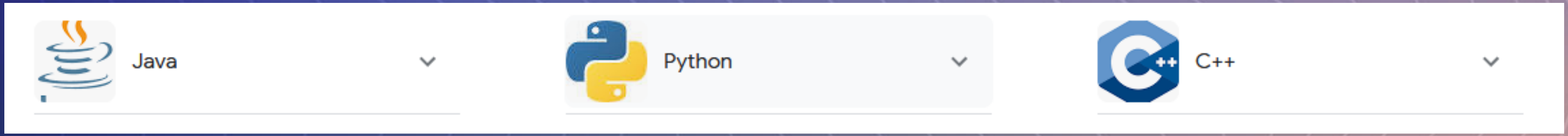


Figure Attribute entry interface in WEKA.

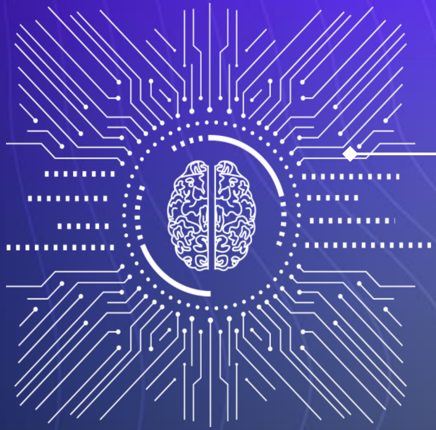
Using program languages

We can use different software languages to code and manufacture software that helps us manage the conservation and restoration of our heritage quickly and effectively.



Example for using C++ language

C++ code to identify satellite images showing sea level rise of the Alexandria coast over the past 100 years

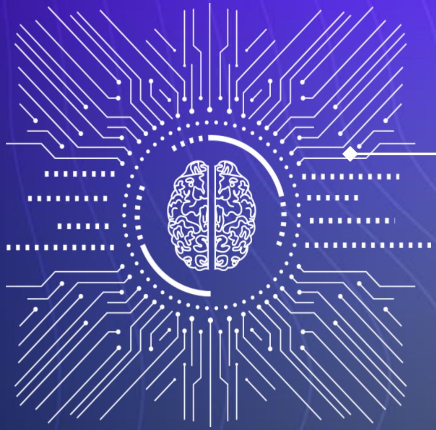


reasonml Copy

```
#include <iostream>
#include <opencv2/opencv.hpp>

using namespace cv;
using namespace std;

int main(int argc, char** argv) {

    // Load the satellite images
    Mat image1 = imread("alexandria-coast-1910.jpg", IMREAD_GRAYSCALE);
    Mat image2 = imread("alexandria-coast-2010.jpg", IMREAD_GRAYSCALE);

    // Calculate the absolute difference between the images
    Mat diff;
    absdiff(image1, image2, diff);

    // Threshold the difference image to highlight changes in the coastline
    Mat thresholded;
    threshold(diff, thresholded, 128, 255, THRESH_BINARY);
```

Example for using machine learning

C++ code to identify satellite images showing sea level rise of the Alexandria coast over the past 100 years



```
    // Find contours in the thresholded image
    vector<vector<Point>> contours;
    findContours(thresholded, contours, RETR_EXTERNAL, CHAIN_APP
ROX_SIMPLE);

    // Draw the contours on the original images
    Mat result1, result2;
    cvtColor(image1, result1, COLOR_GRAY2BGR);
    cvtColor(image2, result2, COLOR_GRAY2BGR);
    drawContours(result1, contours, -1, Scalar(0, 0, 255), 2);
    drawContours(result2, contours, -1, Scalar(0, 0, 255), 2);

    // Display the results
    namedWindow("1910", WINDOW_NORMAL);
    namedWindow("2010", WINDOW_NORMAL);
    imshow("1910", result1);
    imshow("2010", result2);
    waitKey(0);

    return 0;
}
```

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16	Resilience Adaptation Approach for Reducing the Negative Impact of Climate Change on Coastal Heritage Sites through Machine Learning .Yasmine Sabry Hegazi

THE END