ARISTOTLE UNIVERSITY OF THESSALONIKI, GREECE

Topographic Surveying for Heritage Documentation

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NARRATE

Needs for Digital Recording and Documentation of Ecclesiastical Cultural Treasures in Monasteries and Temples

Workshop on Documentation of Ecclesiastical Heritage

December 9-11, 2024

Istanbul, Turkey

CIPA Heritage Documentation

Introduction

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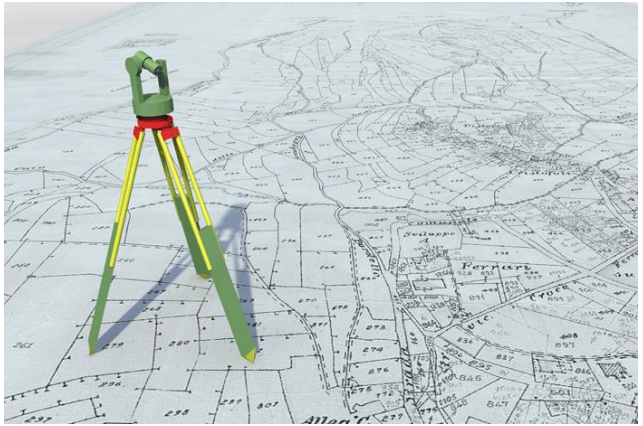
What is topography and why it is important?

What is Topography?

- Topography is originating from the Greek word ***τόπος topos***, which means “place”, and the word ***γράφω graphō***, which means “write”).
- It is the science concerned with the *methods and techniques of measuring*, mainly of geometric quantities, such as *angles, distances, and elevation differences*, at points or between points on the earth's surface, but within a limited area of the earth.

- In Topography, we are interested in recording and mapping the relief of terrain, as well as natural and human-made features.
- Measurement of natural and human-made points.



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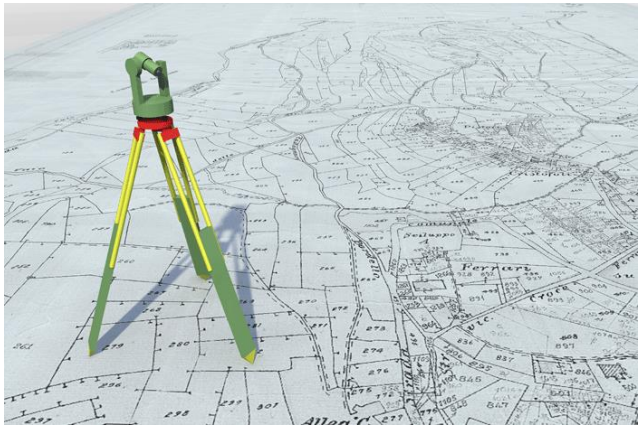
What is topography and why it is important?

Why Topography?

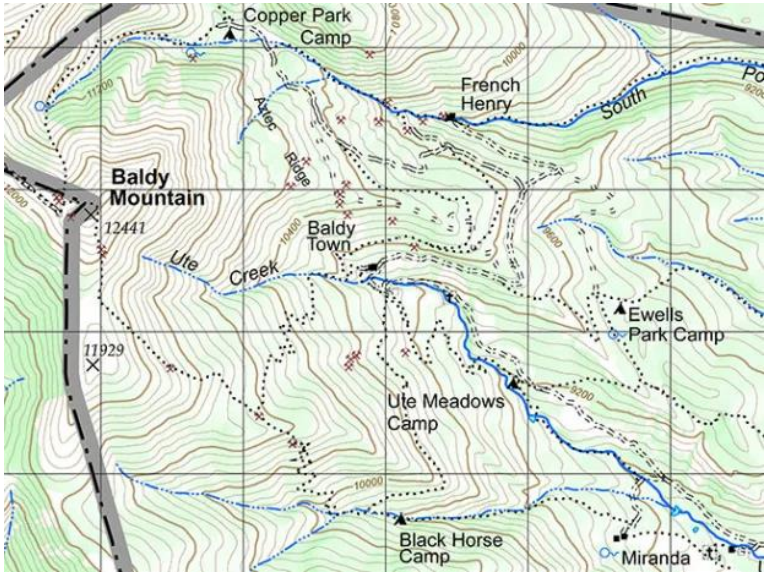
Because everything, or almost everything, that happens, happens in a given and known dimension of space.

- The role of location.
- Reference – Coordinate system.
- The need to have everything on a known (common) frame.



The purpose of topography

- Limited to relatively small areas
- Final product ➡ Representing the earth on a map
  - Topographic Map
  - Topographic Diagram



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The purpose of topography

- In other words, it is about determining the exact geographical position of certain points with coordinates in the local reference system.

Create maps based on geographic coordinates

Angles
Distances

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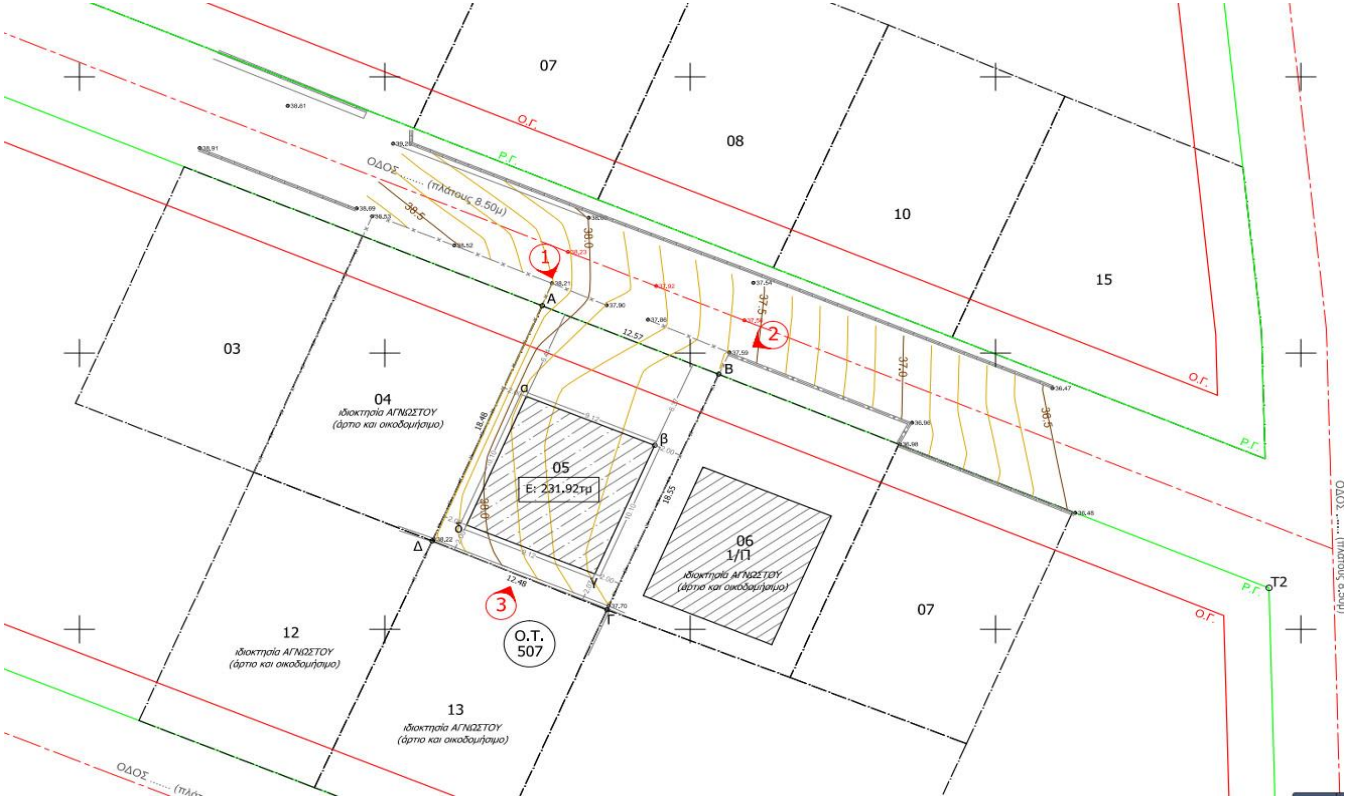
Example of a topographic diagram



Quality of topographic map/diagram

- **Accuracy** — Mapping – Calculations – Drawing
- **Completeness** — Clarity
- **Credibility** — Size - Shapes
- **Performance** — Morphology – Contours

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Quality of Topographic map/diagram

We are interested in:

1. the information displayed is easy and quick to understand.

2. representing real world phenomena/objects with the correct use of symbols.

3. depicting reality as credibly as possible.

4. ensuring the map/diagram contains all the necessary elements for interpretation.

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Applications

Topographic maps have many and varied applications as the map is a communication system:

- Planning
- Environmental studies
- Archaeological excavations
- Technical projects
- Geology
- Agriculture

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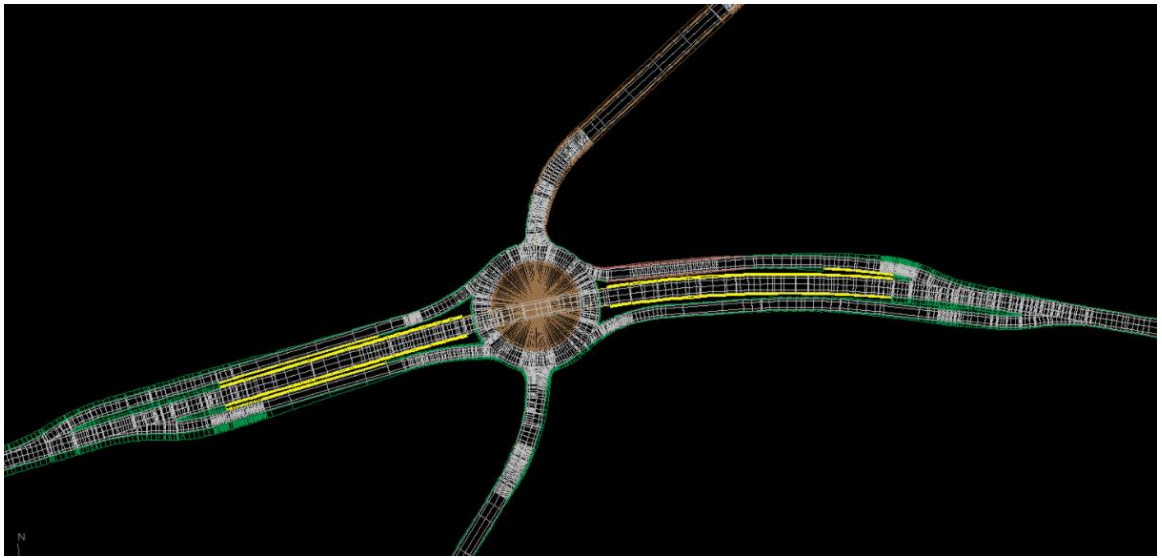
Applications

- Road construction

The designing and construction of roads



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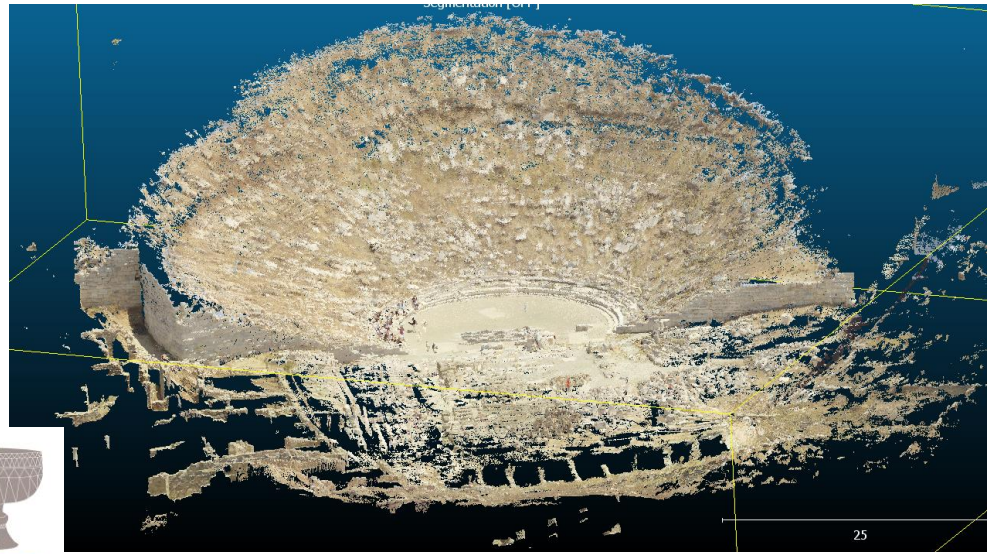
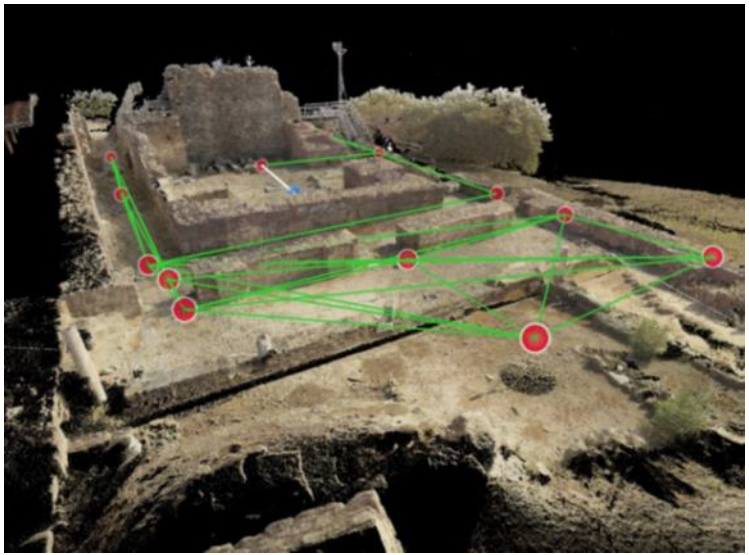
Applications

- Archaeology

Mapping of archaeological sites and findings



Theatre of Delos, Greece



Ancient Pydna, Greece

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Applications

❑Urban Planning

Landscaping is a branch of urban planning that deals with the design of the space in which a settlement, city or other complex of buildings is to be built.

Source : © https://www.terra.gr

Applications

- Monitoring changes in the shape or dimensions of an object

It is the systematic measurement and monitoring of changes in the shape or dimensions of an object.

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Topographic instruments

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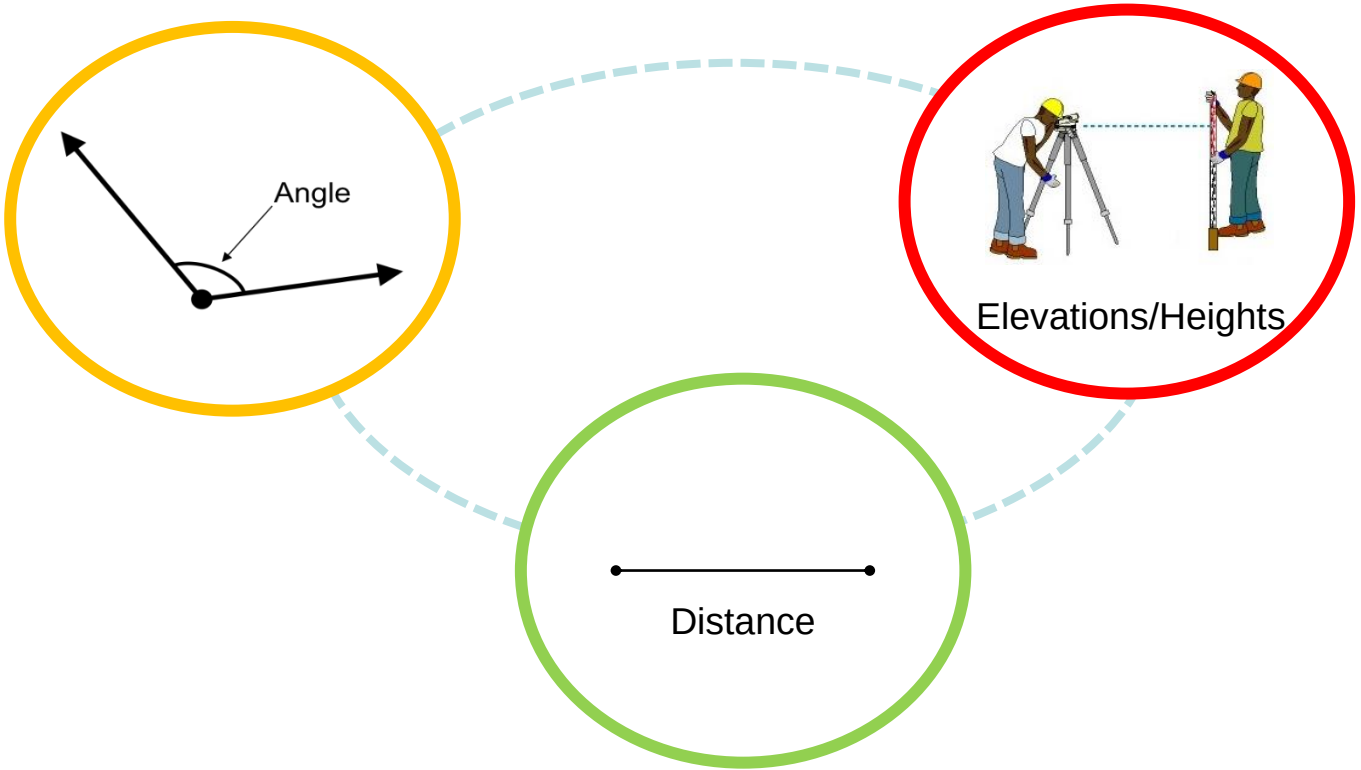
What do we measure?



Topographic instruments

Measuring instruments are divided into three main categories:

1. Distance measuring instruments
2. Angle measuring instruments
3. Instruments for measuring height differences

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Topographic Instruments

- Theodolites
  - *They are precision optical instruments for measuring angles between specified visible points in the horizontal and vertical planes.*

- Geodetic stations – Total stations
  - *They measure both vertical and horizontal angles as well as the tilt distance (slope) from the instrument to a given point.*

- Levels
  - *An optical instrument used to establish or check points in the same horizontal plane in a process known as levelling.*

Topographic Equipment

… and additional equipment!

Tripods

Tapes

Levelling rod

Advanced Measuring Instruments

GNSS receiver with antenna and recorder

Using a pair of GNSS receivers or using one receiver and subscribing to a network of fixed stations, positioning accuracy of ~1cm is achieved.

GNSS

Advanced Measuring Instruments

Laser Scanner

It is used to create digital 3D representations by varying the wavelength of light

Unmanned aerial vehicle

Enables photogrammetric mapping of large areas

Coordinate systems

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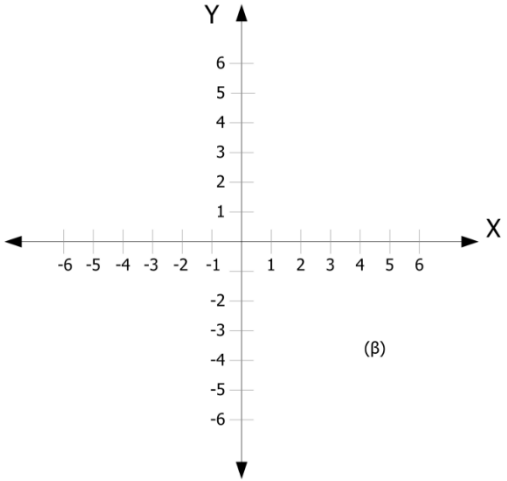
Coordinate systems

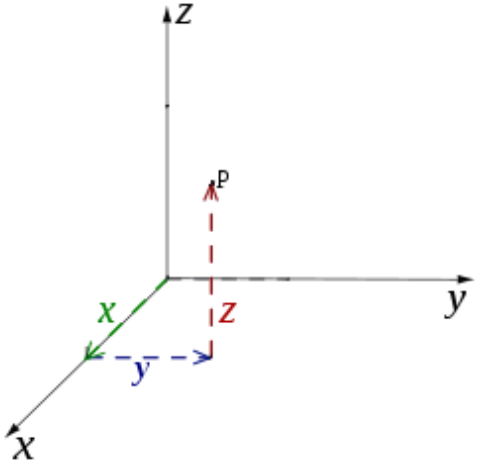
- The coordinate systems used in Mathematics are also used in Topography.
- The purpose of using coordinate systems is to determine the position of an object in space.
- There are several existing systems, although their dimensions are more limited, the most popular being 2D systems and 3 dimensional - 3D systems.

Reference system: The coordinate system associated with a location on the entire Earth.

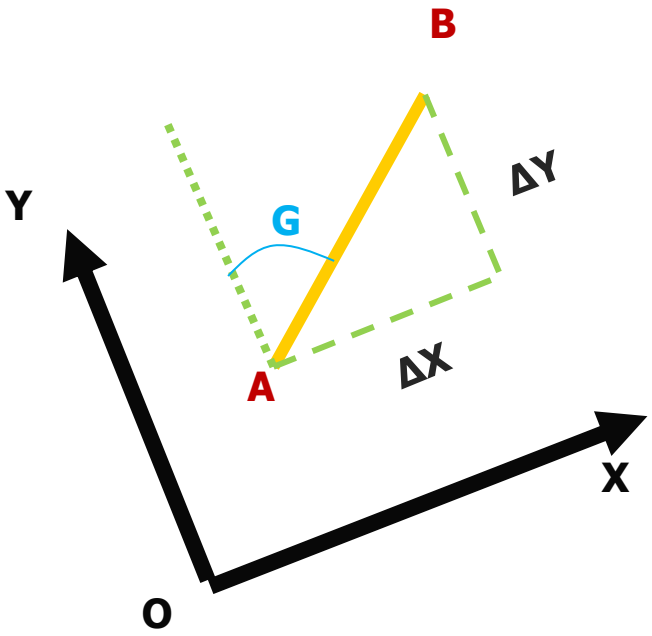
Coordinate systems

- Coordinate systems are important because they help define references.
- A coordinate system uses coordinates to define the position of a point.
- A typical example of a coordinate system is the Cartesian coordinate system. In 2D, two perpendicular lines are defined, and the coordinates of the point are the signed distances to these lines.
- In 3D, three perpendicular planes are defined, and the 3 coordinates of a point are the respective distances to each plane.



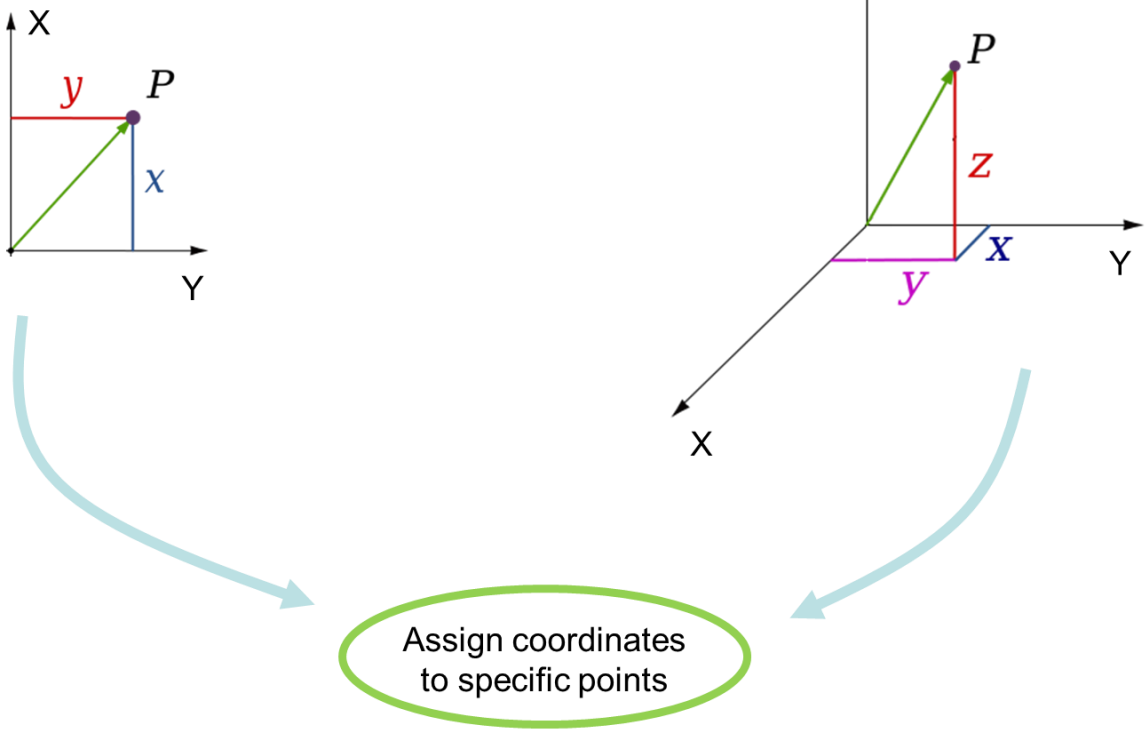


Two known points define a coordinate system

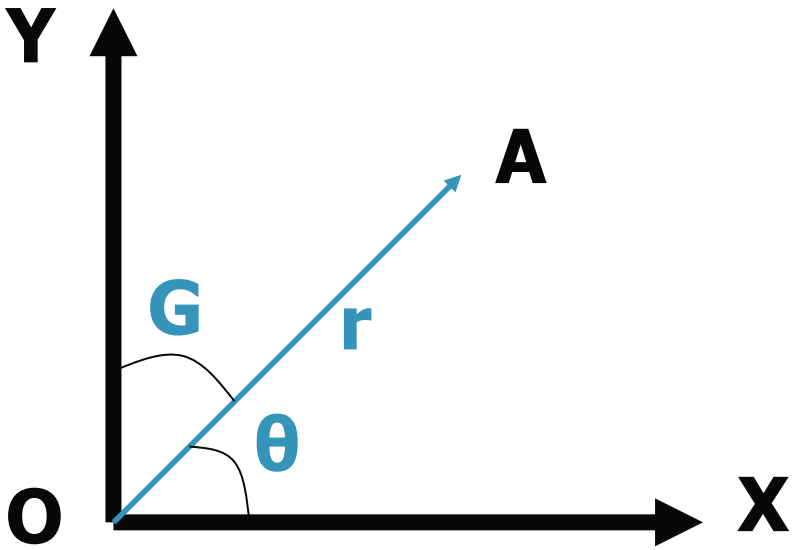


- The 2D coordinate system is defined by the coordinates of the 2 points, i.e.:
  - (X_A, Y_A)
  - (X_B, Y_B)
- This gives us the orientation of the system, i.e.:
  - $\tan G_{AB} = \Delta X/\Delta Y = (X_B - X_A)/(Y_B - Y_A)$
- **G** can be defined as an azimuth or heading angle.

Why do we measure?

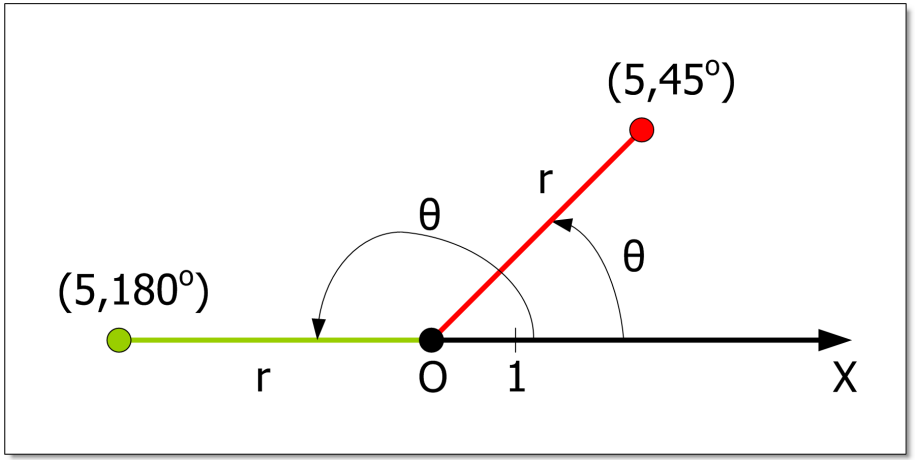


Polar coordinates

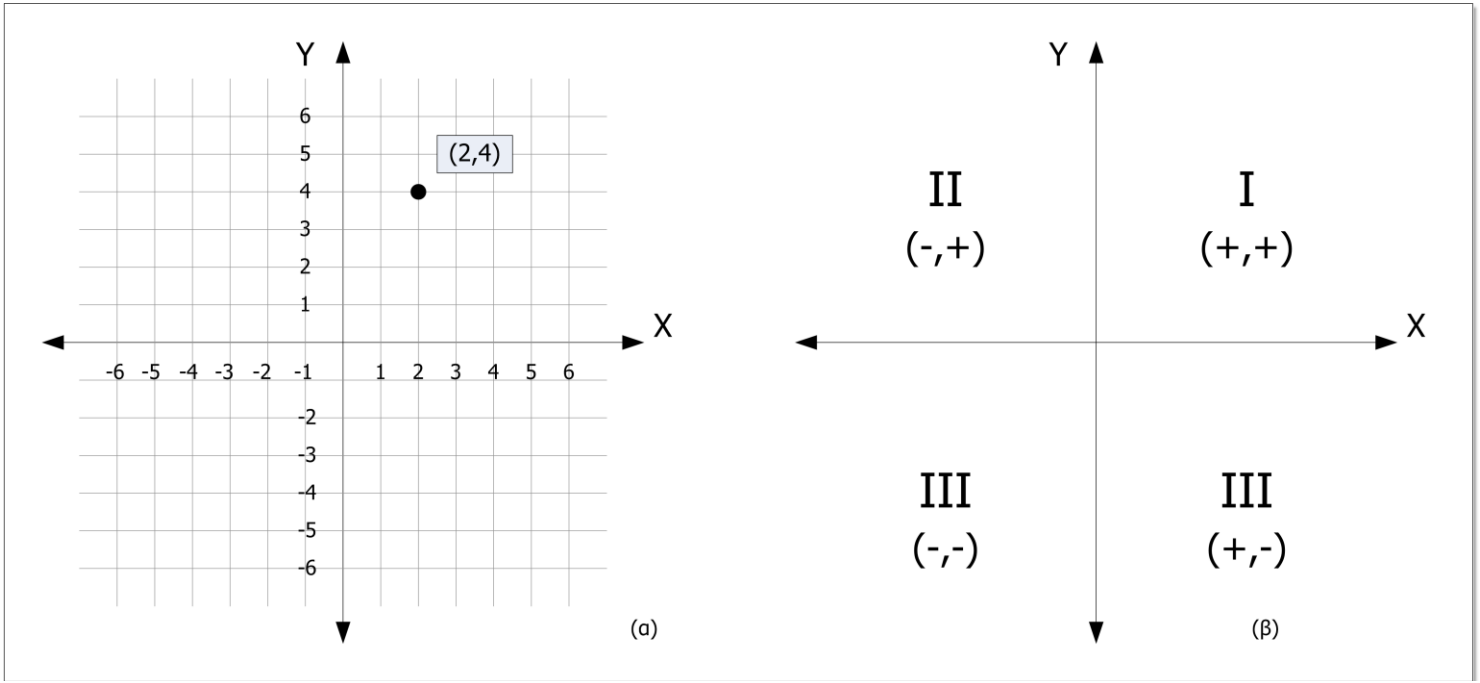


The polar coordinates of a point A are defined by:

(r,θ)



Rectangular (Cartesian) coordinates

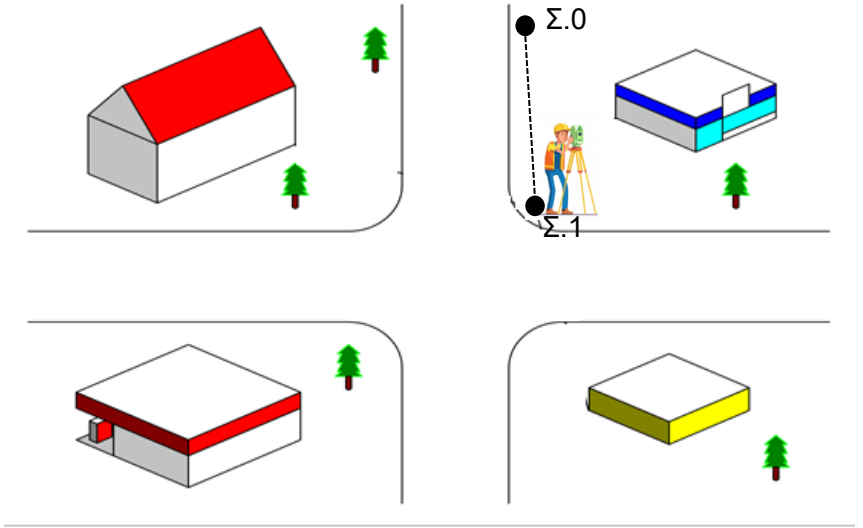


The Cartesian coordinates of a point A are defined by:

(x,y)

Coordinates for Topography

- Cartesian coordinates are the most common way of determining position in space in topographic surveys.
- It is usually necessary to determine the coordinates of a number of points in order to properly map an area.



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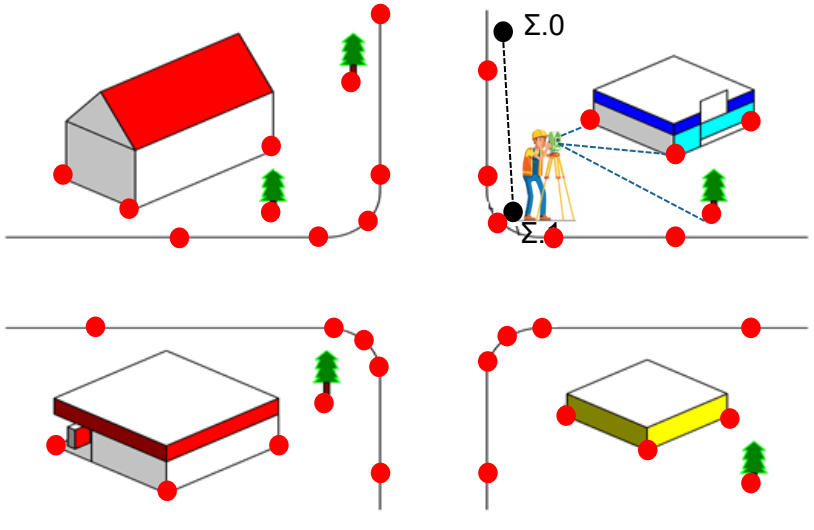
Coordinates for Topography

For these points, a list of measurement is made according to the coordinate system used, which is then used for reporting, i.e., plotting the points and connecting them to create the topographic map of the study area.



Points of interest for mapping the study area

How do we measure?

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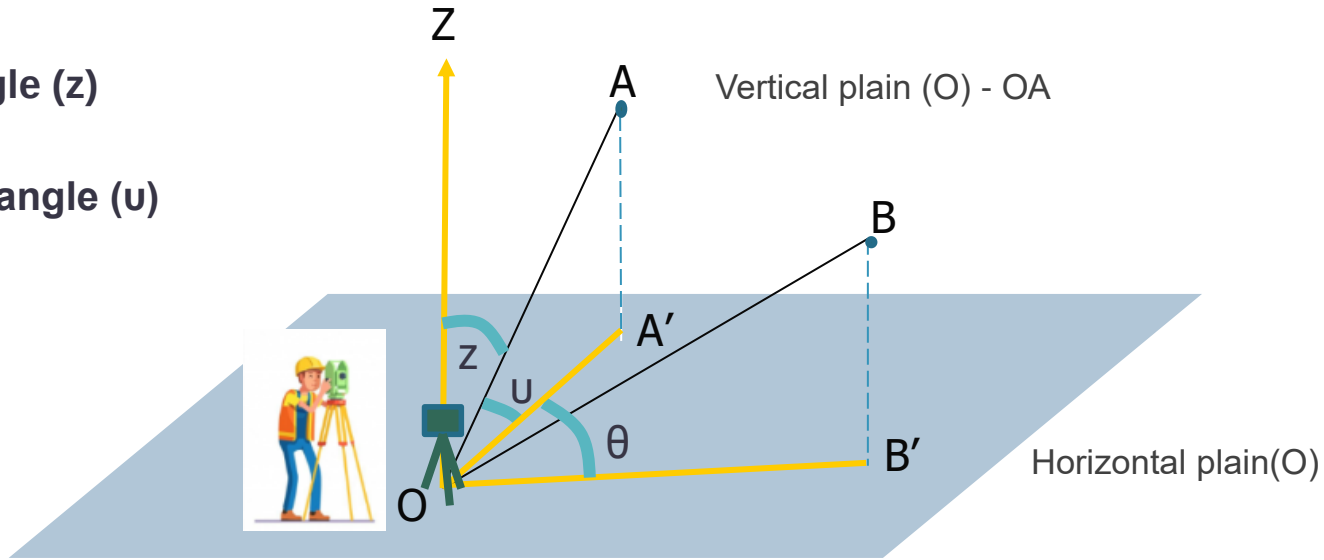
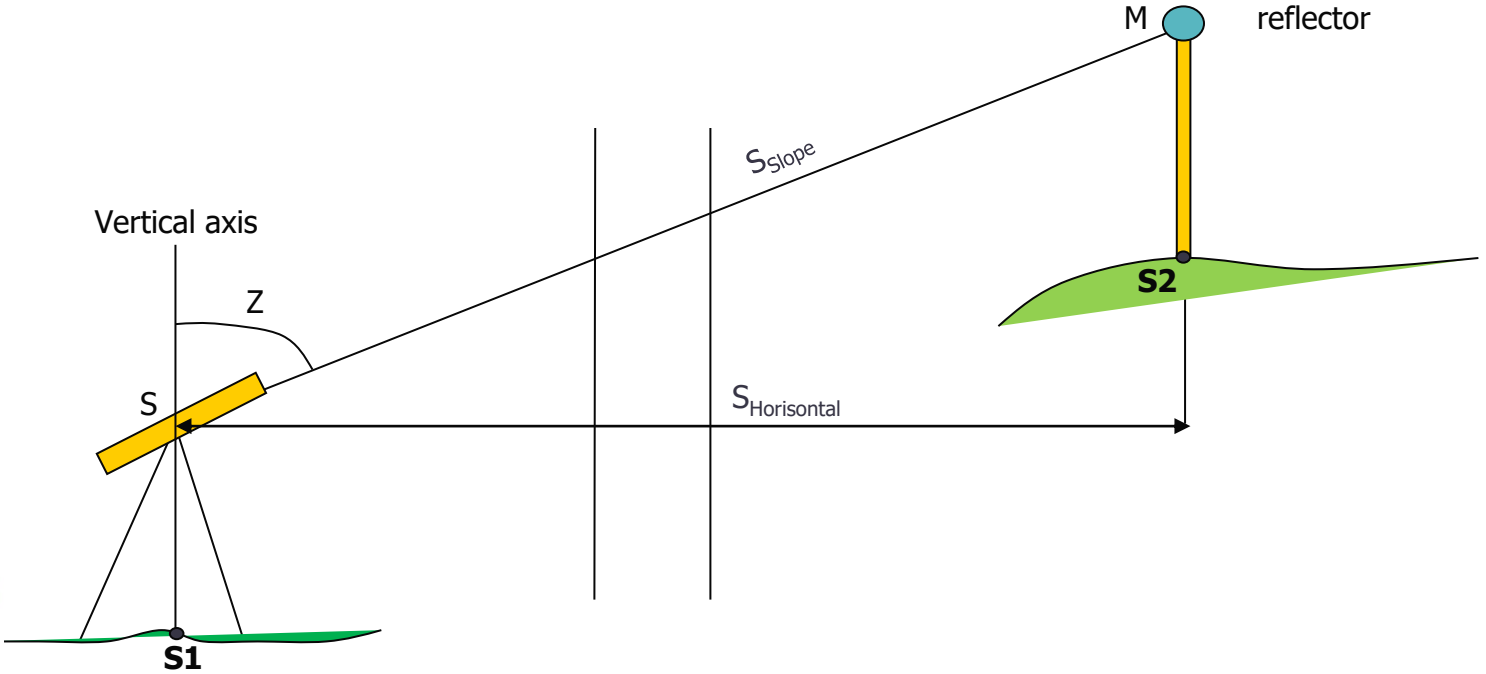
Measuring angles

- **Horizontal angle (θ)**
- **Zenith angle (z)**
- **Elevation angle (υ)**



Measuring distance



Converting measurements to coordinates

The measured angles and distances are used to calculate the positions of points in a Cartesian or geographic coordinate system:

Triangulation:

- Triangulation: determines positions based on angles measured from known points.

Coordinates calculation:

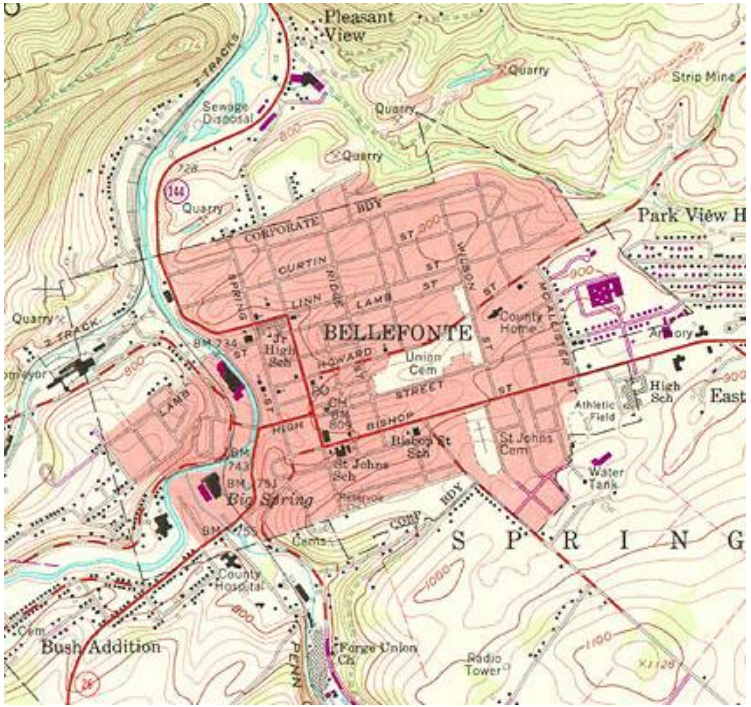
- Trigonometric formulae are used to convert angles and distances into **x, y, z** coordinates relative to a reference point.
- Height (z-coordinate) is calculated from vertical angles and distances.

Create a topographic map

Once the coordinates have been calculated, they are plotted to represent features such as:

- Natural features: hills, valleys, rivers, and vegetation.
- Human-made features: buildings, roads, and landmarks.

The plotting is done using software such as CAD (Computer-Aided Design) or GIS (Geographic Information Systems).



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Topography in action: Survey process for heritage site mapping

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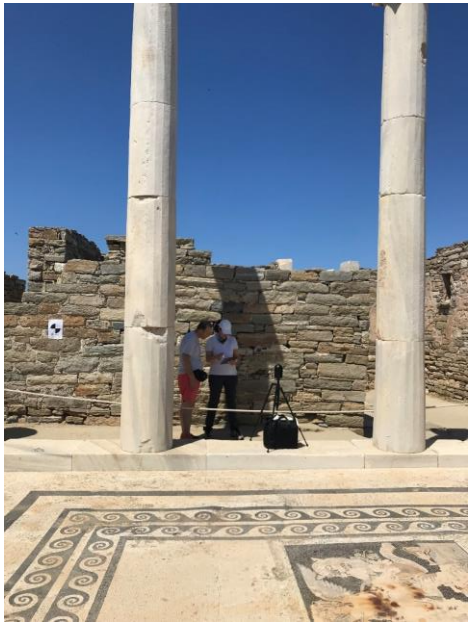
Topographic survey process

Precise methods and specialised tools are used to document the physical features of a heritage site while preserving its integrity during the topographic survey process.

Source : © https://historicengland.org.uk/



Data Collection Delos, Greece

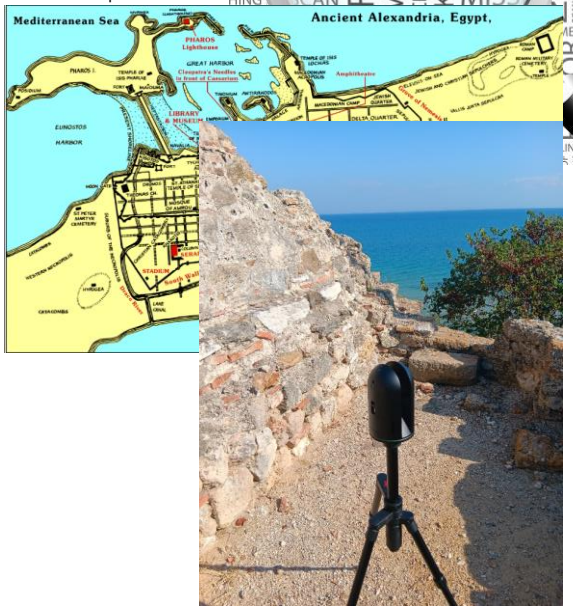
Topographic survey process

Topographic survey process - pipeline

1. Preliminary preparation

- **Definition of objectives**: identify the purpose of the survey (e.g., restoration, conservation, structural analysis, etc.).
- **Gather background information**:
  - Historical maps, documents, and existing site data.
  - Environmental and geographical conditions.
  - Site visits to understand the layout and potential challenges.
  - Selecting appropriate tools and techniques.

Source : © https://www.ancientlocations.net/



Data Collection Ancient Pydna, Greece

Topographic survey process - pipeline

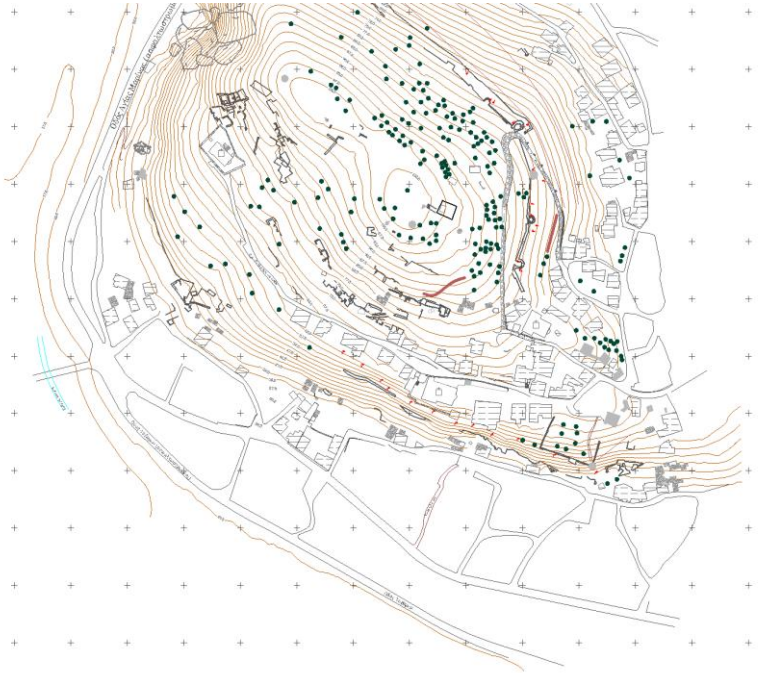
2. Data collection

- **Establish Ground Control Points (GCPs)**:
  - Use GNSS systems to establish reference points
  - Ensure points are stable and well distributed across the site.
- **Field measurements**:
  - Total station: Measure angles and distances to map features.
  - Laser scanning: Capture detailed 3D data of structures and terrain.
  - Drone Surveys (UAVs): Map inaccessible or sensitive areas without physical contact.

Topographic survey process - pipeline

3. Data processing

- **Data integration**:
  - Combining data from different tools into a single dataset using CAD or GIS software.
- **Digital modelling**:
  - Create detailed topographic maps of the site.



Detailed topographical map with contours / Castle of Didymoteichon, Greece

Topographic survey process - pipeline

4. Analysis and interpretation

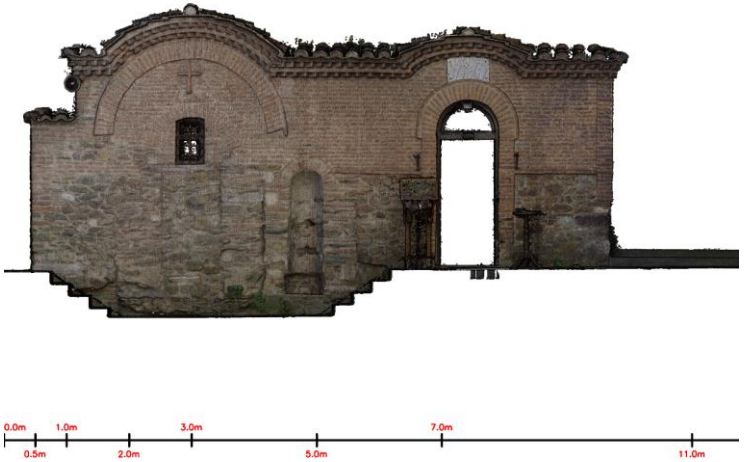
- **Identify features**:
  - Document contours, elevations, and structural details.
  - Highlight areas requiring conservation or further investigation.
- **Comparison**:
  - Overlay historical data with current surveys to identify changes or damage.
- **Structural analysis**:
  - Assess stability and patterns of deterioration.

3D Modelling : Church of St. Spyridon Samos, Greece

Topographic survey process - pipeline

5. Reporting and archiving

- **Create documentation**:
  - Create detailed maps, elevation profiles, reports, etc.
- **Recommendation**:
  - Provide insight for restoration, conservation or site management.
- **Digital archiving**:
  - Store data for future reference or research using digital preservation standards.



Topographic survey process - pipeline

6. Application

- **Use the survey results to guide**:
  - Conservation planning.
  - Restoration projects.
  - Public displays or digital reconstructions for education purposed.

Church of St. Spyridon Samos, Greece

Challenges in documenting heritage sites

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Challenges in documenting heritage sites

Physical challenges

- ❑ Difficult terrain and remote locations.
- ❑ Weathering and natural deterioration.
- ❑ Limited access to vulnerable structures.

Data collection challenges

- ❑ Incomplete historical records.
- ❑ Complexity of intricate architectural detailing.

St. Nikolaos Church Samos, Greece

The need for non-invasive techniques is becoming increasingly important

How Topography overcomes challenges

Precise data collection

- Total station surveys provide accurate measurements.

Digital preservation

- CAD and GIS databases efficiently store and manage vast amounts of data.

Detailed mapping

- Advanced topographic techniques such as laser scanning, drones and photogrammetry capture inaccessible details.
- They can provide enhanced visualisation (3D models).

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Any limitations?

- Cost and availability of advanced tools
- Data management
- Need for skilled professionals

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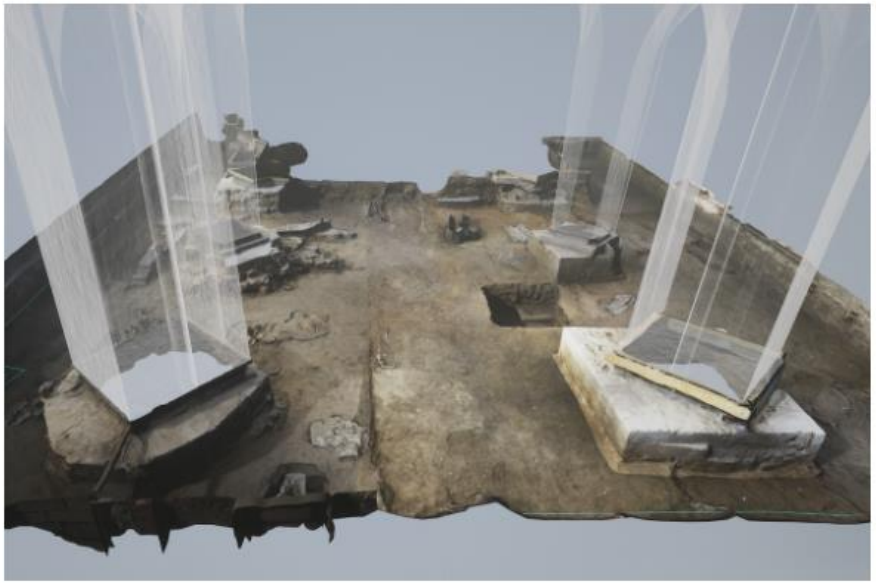
Future trends

- AI and Machine Learning in Topography.
- AR/VR integration for immersive experiences.



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Conclusion

- Combining tradition and technology
  - Using advanced tools of topographic techniques such as drones, laser scanning, and GIS, we can preserve history while respecting its legacy.
- Revolutionising conservation
  - Digital modelling and AI will bring new dimensions to understanding and protecting cultural heritage.

Let's champion research and embrace technology to ensure our cultural heritage is preserved for future generations.

Thanks for your attention!