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BLOCK V: New BIM Modelling Technologies
3D scanning and BIM models, photogrammetry 3D modelling and 3D printing.

Title: GEORREFERENCING AND COORDINATES

1 - Aims.

The objectives of this tutorial are:

- To contextualise the student in geotechnical knowledge.
- To show usable tools at different levels of budget and experience.
- To show different methods of obtaining coordinates.
- To introduce of different geolocation and georeferencing systems.

2 - Learning methodology.

- The teacher will provide an explanation of the material with practical examples.

- To assess practical teaching achievements, each student will write short descriptions and answer the questions provided.

3 - Tutorial duration.

The duration of the tutorial will depend on whether only the reading and synthesis of the material itself is carried out or if, on the contrary, data collection is carried out with some of the tools or methodologies explained, so it could vary between 1h-4h.

4 - Necessary teaching resources.

This document to acquire the necessary knowledge.

Named tools available for data collection:

- RTK.
- Dron.
- Total station.
- Laser distance meter.
- Metro.
- Note blog to record results if necessary.

5- Contents & Tutorial.

Georeferencing and coordinate taking

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Table of contents:

5.1- What is Georeferencing? 3

5.2- Use of georeferencing in photogrammetric projects. 4

5.3- Georeferencing Fieldwork. 5

5.4- Tools for Modern Georeferencing. 6

- 5.4.1- Traditional method. 6
- 5.4.2- Total Station. 6
- 5.4.3- GPS Device. 7
- 5.4.4- RTK. 7
- 5.4.5- Drone. 8

5.5- Georeferencing Office Work. 9

5.1- Georeferencing with Google Earth 10

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5.1 What is Georeferencing?

It is a process derived from the geographical surveying discipline such as 3D digital photogrammetry, born from the paper-based photogrammetry developed in previous centuries.

Current georeferencing is defined as a process that allows us to know with great accuracy the positioning and spatial distribution of different elements that make up the terrain, biotic and anthropic; for this purpose, spherical measurements are used according to the volume of the earth's surface in latitude and longitude values, assigning values to the different points of the surface, these are called geographic coordinates.

Georeferencing is used as one of the main tools of (GIS) Geographic information where the projection of spaces referring to areas and surfaces expressed in *datum.* provide a 2D plane of great accuracy suitable for mapping and topography, operating with pixel map elements as well as images or vector objects such as polylines, vectors or polygons.

We can find different types of coordinates such as:

Latitude-longitude are measured in degrees because they are spherical measurements, they are known as the geographical coordinates, the latitude is developed from the equator and can be framed within (North-South); while the longitude variable is developed in the trace from the Greenwich meridian and can be framed within (East-West); both variables are measured in degrees, minutes and seconds.

Other coordinate systems may be 2D or 3D in nature, depending on the quantities they measure.

Two-dimensional or 2D coordinates are developed on a Cartesian ordinate axis and only count in Cartesian coordinates with 2D values (X,Y), where X is the horizontal value representing east and west; on the other hand Y is the vertical value representing north and south.

Three-dimensional or 3D coordinates use the variables (Z,X,Y) for the referencing of a point, since Z is the one that calculates the elevation below or above sea level in GIS projects or the ground level of our model.

Z being the altitude above or below the sea or the model itself where we want to put the ground elevation and the X and Y axis data showing the location of the object on its axis.

5.2 Use of Georeferencing in photogrammetric projects

The use of measurement methods and the use of coordinates in photogrammetric projects give the three-dimensional resource of the point cloud or polygonal mesh resulting from the processing a closer approximation to the captured element, respecting the proportions of the element.

Georeferencing by taking natural physical points or targets gives greaterrigour to the model, giving it a scientific value as a non-ideal reflection but as a copy of reality, since the choice of X,Y,Z points applied to the three-dimensional model firstly orientates the model, giving it its predefined place in space and secondly scales the model to copy and capture the real distances between the different points, reflecting the dimensions and volume of the three-dimensional model itself.

Georeferencing can be carried out by different methods, either aerial or terrestrial, depending on the tools used, and the accuracy will also vary in this way. In professional surveying work, surveys usually have an accuracy of 20mm+-1ppm.

Before starting the work, it is important to know the framework of the geographic coordinates used in the different tools, to avoid possible later calculation errors, so it is of vital importance for the project to work in all its processes with thesame system of coordinates and location.

The most widely used geographic coordinate and latitude/longitude location system is the *WGS84* or *World Geodetic System 1984, which* is used on a global scale, providing the opportunity to geolocate every point on the earth on the X and Y Z axes. In many places, local coordinate systems are gaining in importance.

The use of the *European Terrestrial Reference System 89* or ETRS89 is promoted in the EU, as well as in coordinate detection products and specialized GPS. This datum is not only compatible with the European GALILEO navigation system, but also with GPS and GLONASS, which means that it is possible to operate on the European continental plate with any of the above systems.

There are a variety of methods for obtaining 3D geospatially-rectified models, using GIS systems, obtaining products such as the raw three-dimensional model itself, the orthomosaic resulting from the previous one with orthorectification adjustments to eliminate the distortions that the human eye and the camera as an imitation of this produces. All this work is obtained by means of physical and digital control points (Markers).

Any visible object placed or not for that specific purpose. With the creation of this data, a large amount of metadata is generated that allows its subsequent use in contour lines and histograms among other analysis tools that reveal different types of constituent data of the terrain, section or chosen area.

It is possible to obtain products such as MDS or DTM: to generate greater results such as contour lines, analysis of watercourses, slopes, gradients, unevenness, among others:

- **(DSM): Digital Surface Model:** These are digital models that represent the existing elements and shapes captured and digitized on the terrestrial surface subjected to the process, such as buildings, or the relief of the terrain itself such as mountains and elements that make them up, such as trees.
- **(DTM): Digital Terrain Model:** These are digital models that represent the shape of the terrain, once the extraordinary elements such as vegetation or infrastructures have been removed, eliminating all elements that are not part of the terrain itself.

With these high-information digital models it is also possible to generate photogrammetrically rectified orthomosaics for the analysis of different studies or interventions in the field.

5.3 Georeferencing Fieldwork

The work of capturing and collecting shorthand data and coordinates in the field can be carried out with various tools. In order to carry out this field work, it is necessary for the technician in question to go to the field to carry out the different actions.

The collected data can be written down manually on a sheet or paper, or digitally stored on a memory card that the device used for this operation may have.

Planning: The data capture operation must start with a knowledge of the terrain where it is going to be carried out, therefore it is good to have studied the relief and disposition of the geological, topographical elements or civil structures of the terrain since the data capture procedure will depend on them.

These control points are provided with coordinates and must be marked by signs such as targets or be easily recognizable within the model, for example a crack, a break or an easily recognizable single element, preferably close to a well-marked edge or a vertex.

Signage: After drawing up the action plan, the physical intervention of the signage is carried out with different elements, such as permanent or semi-permanent signs.

Permanent signs are those that require greater intervention to increase their life and remain visible, and are of interest after the study, while semi-permanent signs are only of interest at the time of the study, and can be built or simply marked with different elements such as construction site waiting times, anchoring of metal rods or marking with special paint.

Data capture: this is the last of the processes carried out in the field with human intervention. In this step, with the help of different tools, the technician can take data at the selected positions, noting down important data in addition to the coordinates, such as slope, inclination, climate or atmospheric weather.

5.4 Tools for georeferencing

Georeferencing has become a major discipline with the implementation of new technologies, from the use of geographic compasses and theodolites to today's complex measurement tools and computerized calculations.

5.4.1 Traditional methods

Rudimentary method of own coordinates created to keep the volume, scale and proportion of the model. In order to create these coordinates, it is necessary to use the physical qualities of the object and space to mark different physical points that are clearly recognizable if there are no automatic recognition targets.

Once the points have been selected, we use a laser distance meter or metre. This taking of measurements will have a higher error in centimeter values than modern millimetric methodologies, but the use of common field and site tools means that it is recognized as a useful methodology that has a tolerable error in its development.

So we proceed to mark the first point, this point must be provided with X,Y,Z values, so it is necessary to measure the height of this and give value 0.000, this *point 1* will be our point of origin, from it, we will measure the distance between the different following points we want to take, using the laser distance meter or a meter.

5.4.2 Georeferencing with total station

Data capture for terrestrial photogrammetry, it is possible to capture georeferenced points with a total station, this electronic device works by means of a distance meter that calculates and a microprocessor that processes the information obtained from the former in reference to an electronic theodolite.

The selection of points is preferably taken by two technicians to speed up the work and diversify the tasks, in this way, one is in charge of taking points with the mobile receiver while the other is in charge of the fixed receiver.

The station emits as a fixed element, emits a signal to the mobile element which is the circular prism to facilitate the reception of the signal and the return of this to the station itself.

Once the signal has been correctly routed, the station quantifies the time elapsed between the output and the return of this signal and quantifies the distance between both elements according to this time, quantifying and locating the exact location of the base of the total station itself, which acts as a receiver.

In order to carry out the procedure properly, different factors that may hinder the work must be taken into account, such as weather conditions, and preferably its operation by 2 operators.

5.4.3GPS device

A GPS device is a device that receives a satellite signal collected by ground stations through electromagnetic signals to coordinate different values and locate its location. There are different types of GPS devices and their accuracy may vary according to their price.

The device for GPS topographic documentation has an antenna that must be placed at the point in question, this works in conjunction with a Pda or electronic notebook, the accuracy may depend on physical or climatic factors that may obstruct the transmission or reception signal as well as may also vary depending on the number of satellites that can be captured.

5.4.4 RTK

The RTK coordinate acquisition system, short for Real Time Kinematic, can work with the various signal navigators such as the European Galilleo or the famous GPS, providing real-time information on the state of the coordinates.

In order for the equipment to work properly and obtain the best possible results, it is necessary to connect to the location system by means of at least three satellites, in order to coordinate the distances between the different satellites. The system uses the RTK device as a base station receiver that connects with different mobile units that compare their distances and triangulate with the base station. This system uses UHF modems among other sensors to capture the information in real time.

The RTK data collection system has an error rate of less than 1%, respectively 1 centimeter ± 2 parts per million horizontally and 2 centimeters ± 2 ppm vertically.

5.4.5 Georeferencing with Drone

Within the aerial photogrammetric technique we must distinguish various aspects in relation to georeferencing, since by the very nature of aerial photogrammetry this discipline will be one of its main points of support for obtaining sub-centimetric results in the capture of large surfaces.

Therefore, we will pay special attention to various aspects of interest that are performed during the data capture mission, such as: The Drone model, Type of flight or the use of physical georeferenced control points or later implemented in the model as reference points.

- **Drone model:** As a general rule, drones can achieve good data acquisition results regardless of their model. The most modern drones are equipped with more advanced technology such as their own flight modes, collision sensors or better cameras, which is of great interest for photogrammetric science. Among the improvements that a modern drone can have is the georeferencing of the captured images, each image captured by the flight mission will be assigned withthe coordinates in which the drone was at the time of capture, this tool that provides each image with certain coordinates, will help in carrying out the operation with the greatest possible route precision, as well as in future processes in the composition of the model in the first phases such as the alignment of photographs, ordering more effectively and quickly the images subjected to data processing according to their coordinates. In the event that the drone itself generates coordinates in its photos and GPS location, the type of coordinates must be respected, as the use of the point cloud creation and management programme may generate an error that makes the production of the three-dimensional product itself unfeasible.

- **Type of flight mission:** Many current drones come with predefined flight options such as points of interest or target tracking or 360º photographs, which can be useful for maintenance and control tasks, using the drone as a multipurpose work tool, it is also possible to add greater value with the use of specialized control software for missions, this type of software used in mobile terminals such as smartphones or tablets use the geolocation obtained by the control device itself that is connected to the controller, to act as a GPS signal generator for the pilot himself as well as a GPS signal receiver for the drone. This type of programme uses mapping applications to guide the routes and missions assigned to the drone, agreeing perimeters, distances and routes within the areas subject to the data capture process.

- **Physical Control Points:** To add more precision to the data capture for its implementation in better results in the following processes, precise coordinates can be taken by means of topographic devices and marked in the field by means of different elements such as targets. Once the first office work processes are carried out generating data, the said marks are visually searched for within the point cloud and by means of the tools provided by the programme, the different positions are selected and given the values of the coordinates previously extracted; once the corresponding coordinates have been assigned their positions, the alignment process must be repeated, to rectify the error that may have been captured during the previous point cloud sample.

- **Digital Reference Points:** Point cloud management programs have several tools as seen above to correct and apply accurate changes to the model with the highest possible confidence; after the point cloud is generated, the user can select or create counterpart points that have not been collected by visually marking them in all the photographs that appear, this point will be given more precise coordinates within the point cloud when the process is restarted to implement the changes and corrections.

5.5 Georeferencing Office work

After obtaining the physical data either by control points, images or both cases, the data must be subjected to various processes to be able to give value, being able to perform thanks to these coordinates through its implementation in various programs, various actions of georeferencing and shaping of the results in 2D and 3D resources that you want to create with their support.

Computer aided drafting is one of the main uses of coordinates, to create two-dimensional documentation of the captured terrain, very useful for planimetry and mapping.

Technological progress means that thanks to various programmes and disciplines such as photogrammetry, these coordinates can be implemented or obtained in different ways. It is possible to georeference images that have been taken without any value, or to give geographic value to various points that may make up the point cloud of a three-dimensional photogrammetric resource, among other options...

We can find various photogrammetry programmes that allow us to provide the images with coordinates, this tool is used by a large number of professional programmes such as Pix4D, Metashape or Reality Capture, by means of which the implicit coordinates can be included in the photographs themselves from the first moment of processing, as is the case of photographs captured by drone missions.

It is possible, using a simple tool similar to a notepad with blank tables, to insert the values annotated or digitally documented in the terrain data acquisition. This process is applicable to both photographs and a selection of points.

In the case of having inserted already georeferenced photographs in the programme, the programme will start to work with these values, scaling the model according to the proportions that the control points mark between them in terms of distance. On the contrary, if any type of process has been carried out and the coordinates are manually inserted in the programme, the processes must be carried out again to adjust the values according to the adjustment provided by the coordinates, obtaining a scaled and oriented three-dimensional model.

5.6 Georeferencing with Google Earth

One of the most affordable methods for georeferencing a project is the use of Google Earth or Maps applications. Although we recommended the use of the European geographic referencing system ETRS89, Google Earth only works with WGS84 latitude/longitude geographic coordinates based on the GPS system; this is a worldwide system that runs global datums and estimates an error calculation of less than 20 m.

6 Annexes

Georeferencing: The process by which an element is provided with coordinates within a cartographic or spatial entity where its exact location is known and marked.

Scaling: The process by which an element with its own measurements and volumes is subjected to a correction, of higher or lower measurements and volumes, until the desired result is achieved.

Orient: The process by which an element is framed in space in specific directions and parameters.

Geotechnics: Science that studies the mechanics of soils.

Coordinate: References, endowed with numerical values that mark elements of interest within mapping, referencing or three-dimensional modelling systems.

Datum: Abstract coordinate system with a reference surface (such as geoide, ellipsoid, sea level) that serves to provide known locations to begin surveys and create maps.

GIS: Abbreviation for *Geographical Information System*, these are electronic tools integrated in software that facilitate work on geographical data.

Orthomosaic: Product obtained by rectification and visual corrections of geometric distortion applied to a three-dimensional model from which it has been possible to obtain a continuous mosaic that forms a single image.

Surveying: Refers to topographic surveying, in reference to the set of geographic data collection activities, datum-coordinates that can be applied in this process together with their methodologies and the use of specialized tools.

Navigation system: Refers to the satellite geolocation of an element by exchanging signal ranges from any medium on the planet that is located at a point in the lithosphere, hydrosphere or air environment.

Control points: Coordinate points used to orient and scale the three-dimensional model obtained by photogrammetric science.

Target control points: Portable physical elements that can be reused or not, where the coordinates of that point are marked in situ by means of specialized tools.

Natural control points: These are control points that will help to scale and orient the model, but are obtained by taking and giving coordinates to elements that make up the model itself, such as a singularly shaped stone or the vertex of a building.

Noise: These are elements that have not been captured in good conditions due to incorrect field work or are elements that are of no interest in the composition of the model, but appear in the background of the image. These can appear as loose points, protuberances. Deformations...

Contour lines: These are lines that connect locations with the same values within a plane. Among the studies that can be carried out on the photogrammetric model, we can find temperature or altitude.

Histograms: A representation of data in the form of a bar chart that provides a wealth of information about the model.

Laser distance meter: An electronic tool available in various formats, either stand-alone or integrated into other tools, which launches a visible laser beam to measure the distance at which it is being aimed.

Drone: Unmanned aerial device, operated from the ground.

Flight Mission: Set of elements that make up a pre-established automatic flight, such as the route, altitude, number of photographs to be taken, speed or time of completion...

7 Deliverables

The student will have to take a multi-choice test with 3 options, where only 1 is correct.

8 What we have learned

The student has learnt basic knowledge about coordinates, the type of coordinates used in modern georeferencing, as well as learning about the different tools with price/result variationthat can be used to carry it out and to be able to provide the 3D model with geometric and typological realism.