INTRODUCTION TO PHOTOGRAMMETRY

Erasmus+ Project ID: BIMVET3 2020-1-ES01-KA203-083262

This Erasmus+ Project has been funded with support from the European Commission. This publication reflects the views only of the authors, and the European Commission and Erasmus+ National Agencies cannot be held responsible for any use which may be made of the information contained therein

Co-funded by the Erasmus+ Programme of the European Union

BIMVET3

1- Aims:

The objectives of this document are:

- To contextualise the student in photogrammetric matters.
- Theoretical knowledge about the existence of different capture and processing tools.
- To show the student various use cases that can be used in the field of photogrammetry.
- To provide students with a general overview of the possible uses of photogrammetry.

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.

- Photographic camera.
- Dron.
- Processing programs.

Co-funded by the Erasmus+ Programme of the European Union

3- Tutorial duration:

The duration of the tutorial will be conditioned if only the reading and synthesis of the material itself is done or if, on the contrary, some of the tools or methodologies explained are explored, so it could vary between 1h-4h.

4- Necessary teaching resourses:

This document is necessary to acquire basic knowledge.
Named tools available for data collection and processing.

Co-funded by the Erasmus+ Programme of the European Union

CONTENTS

Co-funded by the Erasmus+ Programme of the European Union

BIMVET3

CONTENTS

Co-funded by the Erasmus+ Programme of the European Union

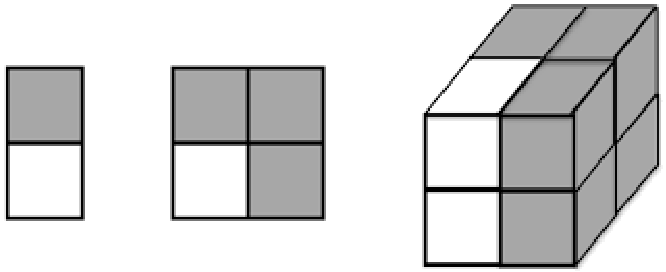
BIMVET3

1. What is Photogrammetry?

Co-funded by the
Erasmus+ Programme
of the European Union

1.1. Definition.

Co-funded by the Erasmus+ Programme of the European Union

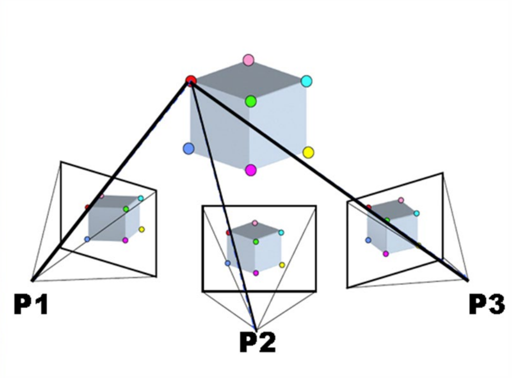


Digital photogrammetry is a process of digitalisation of information by which it is possible to reconstruct morphologically, volumetrically and chromatically a physical element such as the terrain, objects or constructions. By transforming the 2D metric information contained in the photographs, such as space and depth as well as texture, processing and converting it into 3D information, obtaining as a result point clouds that represent the above values.

1.2. How is it done?

Photogrammetry can be categorised as aerial or terrestrial depending on the means and tool used to develop the fieldwork, firstly, it is developed using a camera in the case of terrestrial or a drone equipped with a camera in the case of aerial.

Digital photogrammetry is based on a computation performed by specialised software that transforms the 2D information collected in the photographs and converts them into 3D, adding additional values such as volume or depth.



The main computational tool is carried out by finding homologous points in the different photographs, through this process the relative distances between the point and the photogrammetrist are calculated, in order to triangulate and assign a coordinate on the X and Z axes to that point.

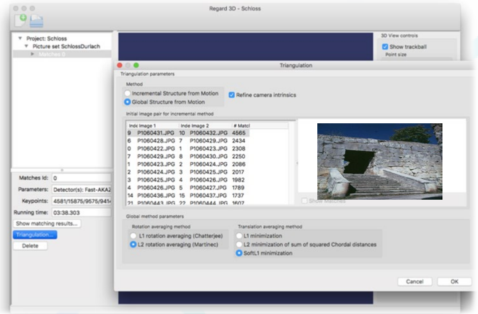
1.2. How is it done?

Co-funded by the Erasmus+ Programme of the European Union

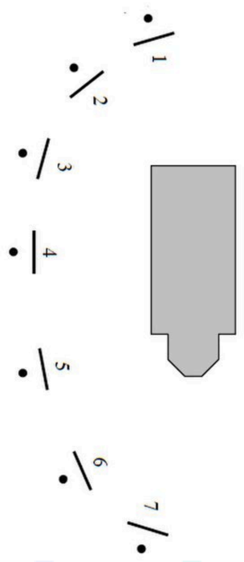
The photographs taken of the object, property, building or land in question are loaded into a special program where the computation is developed, creating homologous points by overlapping the photographs, taken with concise angles and shots to correctly develop their union, interspersing perfectly visible parts that serve the program to select and compile them, thus creating the overlapping areas. These overlapping areas are the common zones and parts existing between 2 or more photographs.

The programme creates homologous points by analysing these common areas of overlap, selecting common points. The more times a point is collected, the more accurately it is represented, and the process is carried out as shown in the images below.

An overlap of more than 70% is always recommended in order to make the process of linking and processing points more efficient.



1.2. How is it done?

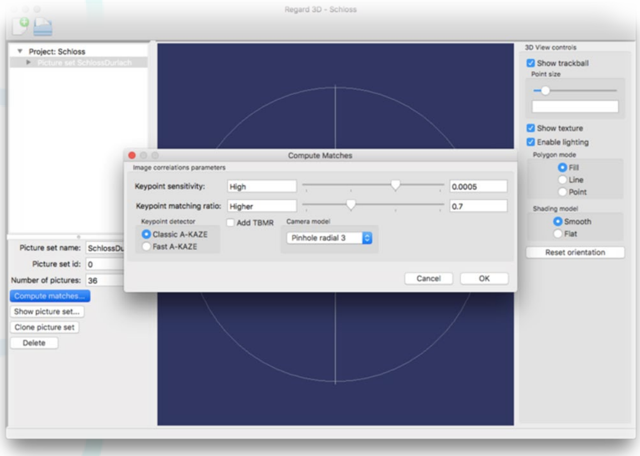


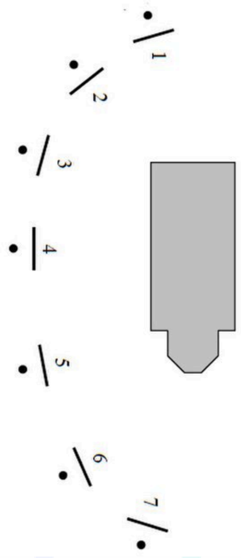
- **Fieldwork** The 2D photographs can be taken on site or in a studio under controlled conditions.

- **Tools**. Depending on the tool used for data collection, it can be mainly aerial with the use of e.g. drones or terrestrial with a reflex camera.

1.2. How is it done?

Co-funded by the Erasmus+ Programme of the European Union





- **Office work** This is carried out after obtaining data, with the help of computer equipment and specialised software, by means of which the processes of obtaining magnitudes and assembling three-dimensional information are carried out.

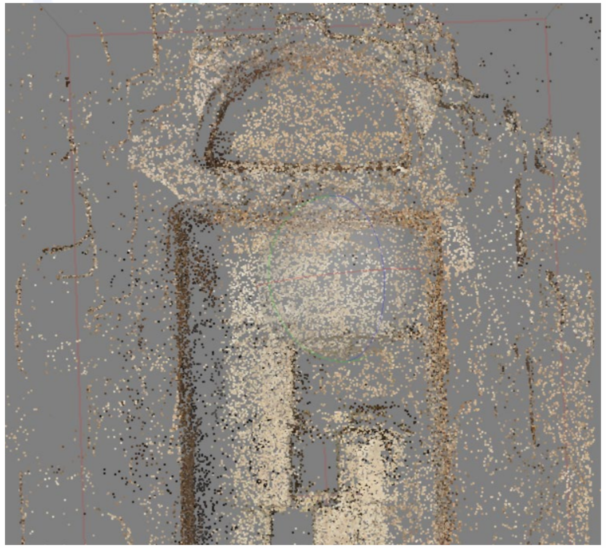
- **Tools** These can be point cloud assembly software, editing software and other programmes that allow work for different uses.

1.2. How is it done?

Co-funded by the Erasmus+ Programme of the European Union

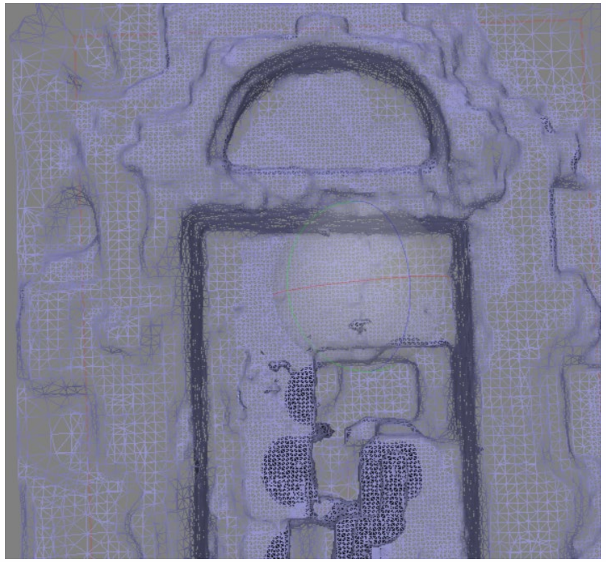
The results obtained immediately after the previous image processing are first of all the so-called point cloud, where the homologous points found are displayed and derived from this, it is possible to create the so-called polygon mesh, which is the unified and solid representation of the point cloud.

Point cloud



Set of homologous points documented in the photograph with X,Y,Z coordinates.

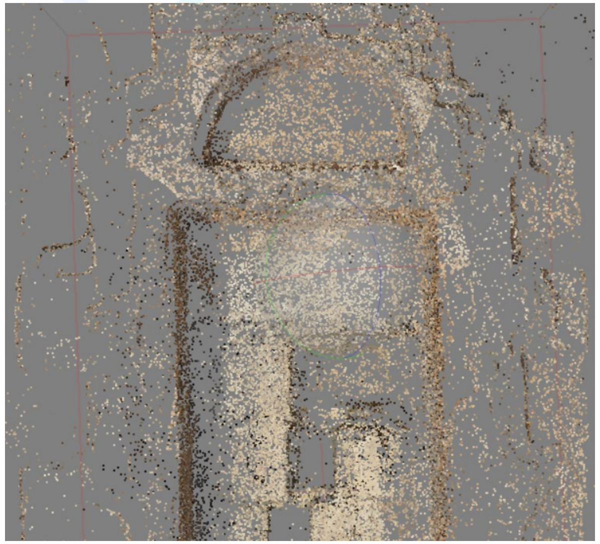
Polygonal mesh



Union of homologous points acting as vertices, coherently joining together, creating a polygonal figure with surfaces.

Point cloud:

The capture of reality by photogrammetric programmes can generate, contrary to the results of a laser scanner, the subdivision of the process of obtaining a point cloud in two, a simpler primitive one and a dense one formed by a greater number of points.



First point cloud, resulting from the alignment of the processed images.

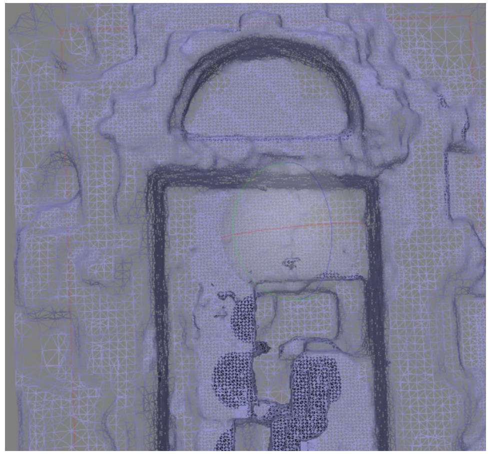
Densified point cloud, by triangulating new points in relation to and on top of the previous cloud.

1.2. How is it done?

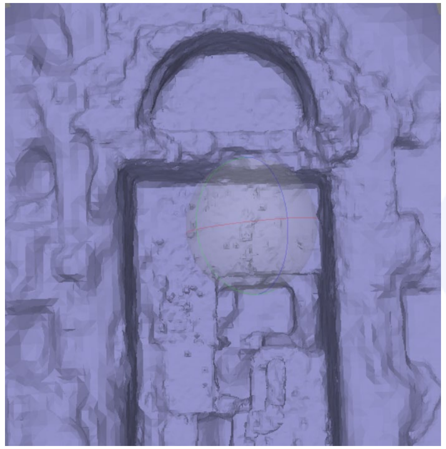
Co-funded by the Erasmus+ Programme of the European Union

Polygon mesh process:

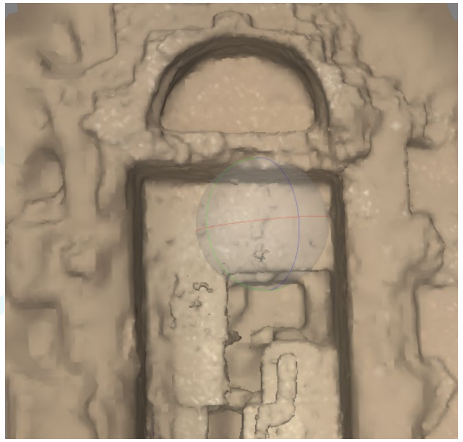
The polygon mesh is made up of a large number of homologous points that form the vertices of the polygons that make up the mesh, these polygons can acquire different shapes, as well as filling their faces, colouring them and texturing them according to the pixels of the processed images.



Wire mesh.



Shaded mesh.



Coloured mesh.

Textured mesh.

1.3.1. Camera.

Co-funded by the Erasmus+ Programme of the European Union

Cameras: Cameras are the main tools used within the photogrammetric technique, these are responsible for capturing images taken from angles and concise positions to obtain from them the subsequent 3D documentation.

The Mobile phone cameras or the commonly used reflex cameras are the main tools of photogrammetry. Photographs must be taken with a specific methodology so that there is an overlap of more than 70%, so each photograph must capture 70% old information and 30% new information. This gradual pattern to be applied until the last cm of the element to be documented is captured.

1.3.1. Camera.

Co-funded by the Erasmus+ Programme of the European Union

Lenses:

One of the main mechanisms of cameras are the lenses or photographic objectives, these parts are usually the most striking of the whole camera, usually consist of a cylindrical plastic shape topped with a glass on its outer base, this is the lens, a simulation of the human eye. Lenses can be interchangeable in SLR cameras and is one of the most important parts of the camera's operation and on it depends largely both the effect and the quality of the image captured.

Without the camera lens and its lens, the rest of the mechanism could only capture the ambient light, this is where we find the term photographic focal length, this is measured in mm and is the representation of the distance between the sensor and the lens, so the longer the distance the smaller field of view is possible to capture, as it is the manual zoom is the one that can adapt this magnitude within the parameters of the lens.

.

1.3.1. Camera.

Co-funded by the Erasmus+ Programme of the European Union

Lenses for photogrammetry:

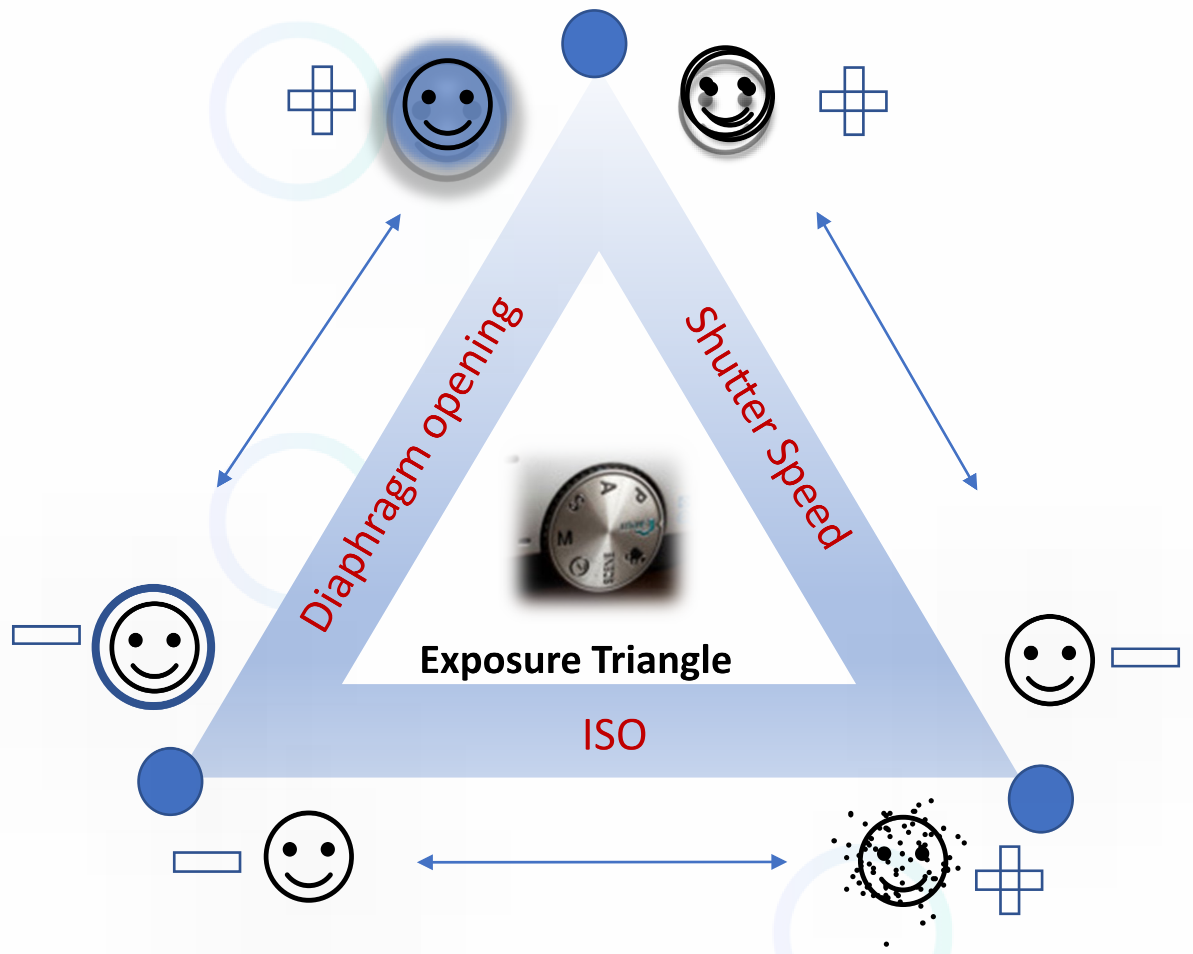
Zoom Lenses: Zoom lenses, are the most consumed throughout the world, because the big companies have manufactured these lenses as a default item for the sale of their cameras, these are lenses adaptable to lighting conditions, have a good image quality, are easy to use.

Fixed Lenses: These are fixed lenses, which have a single focal length so they cannot physically zoom, they are lenses that capture a large amount of light, which makes them able to work efficiently in places with low illumination.

The 50mm fixed lenses are the most used in the photogrammetric field because of the little field distortion they produce, while other lenses such as wide angle or fisheye are discarded from photogrammetric use, because they obtain the opposite effect.

1.3.1. Camera.

Co-funded by the Erasmus+ Programme of the European Union



Exposure:

The exposure in a photographic camera, is the amount of light that receives the camera's sensor receives, different variables depend on it that each one in a different way, adjust and mismatch the light composition that is applied to the capture, this has repercussions in colors, illumination or brightness.

There are different editing modes for the realization of the photographic capture:

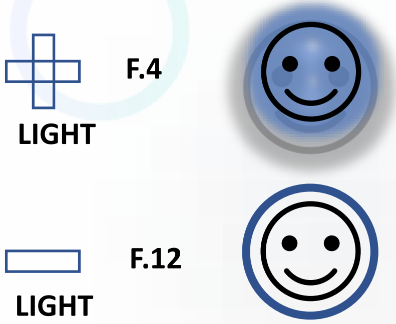
P: ***Automatic.***
A/AV: ***Aperture Aperture.***
S/TV: Shutter speed.
M: ***Manual.***

ISO can be changed in each capture mode.

The variables are dependent on each other, a good photograph is based on the optimum point of calibration of the variables according to the light conditions of the environment, these are represented in the so-called exposure triangle.

1.3.1. Camera.

Co-funded by the Erasmus+ Programme of the European Union



Diaphragm Aperture: It has a direct relationship with light, it consists of the opening and closing action of the lens to control the amount of light that passes through it.

The photographic or diaphragm aperture is calculated in f-stops and its numbering is indirectly proportional to the amount of light it lets through, for example an F.12 lets less light through than an F.4 configuration.

The choice of aperture is of great importance for photogrammetry, on it depends mainly the future calculation of depths. The photographic aperture is also directly related to the depth of field captured in the image, because the larger the aperture of the lens, the more blur it will have on the elements that are not captured in the foreground, distorting all the elements that are behind it; the smaller it is, the better focus it will have and therefore the greater sharpness we will find in the representation of all the depths and distances.

1.3.1. Camera.

Co-funded by the
Erasmus+ Programme
of the European Union

1" Slow speed

Opening time

1/1000 Fast speed

Opening time

Shutter speed: It has a direct relationship with the shutter mechanism, a mechanism that opens and closes inside the camera to allow light to enter the camera, the speed at which it performs the manoeuvre is variable and has an impact on the shutter speed. The shutter speed is measured in fractions of seconds, although it can also be implemented with whole seconds.

It therefore affects the exposure of the sensor in the following way:

Rapidy repeated manoeuvre: The shutter is kept open for a shorter period of time, which allows less light to pass through and produces a darker picture.

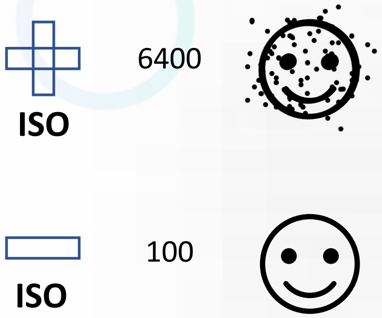
Slowly repeated manoeuvre: The longer the shutter is held open, the more light it lets through and the brighter the picture.

If the shutter is kept open for too long, it can degenerate the picture with the slightest movement of the camera.

BIMVET3

1.3.1. Camera.

Co-funded by the Erasmus+ Programme of the European Union



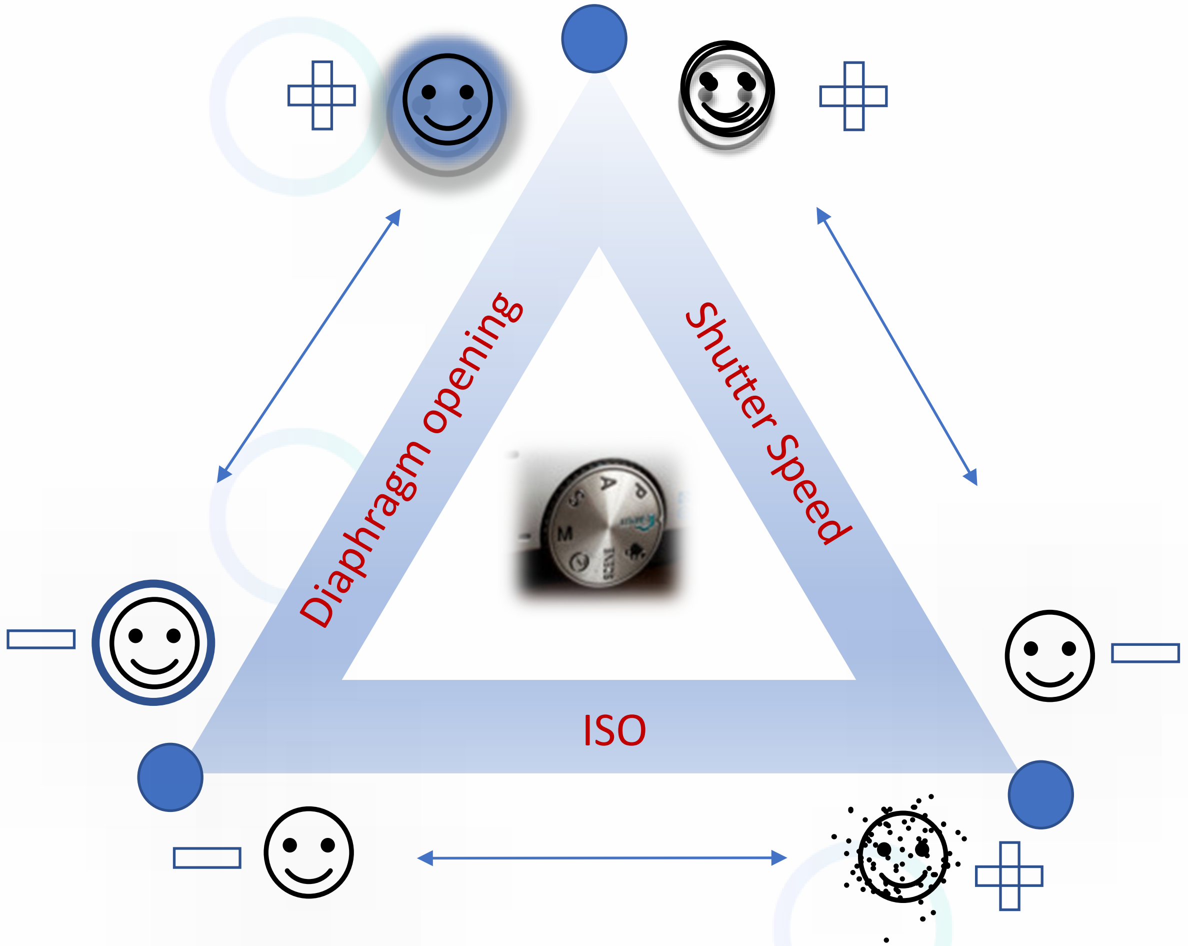
Photographic ISO: It is a direct exposure variable of the sector's sensitivity to light, so it has a value of darkening and lightening the photograph.

By increasing the ISO the sensor will be more sensitive to light, so it is possible to capture images in dark environments.

In environments with a lot of natural light, it is possible to use minimum ISO, if there is shade 200 increasing according to the darkness, but always as a last resort, because abusing the ISO can considerably worsen the quality of the image, encourage the appearance of graininess and distortion of colours and textures.

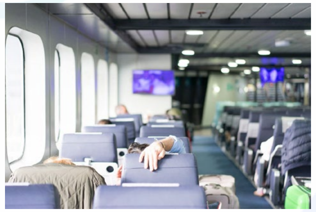
1.3.1. Camera.

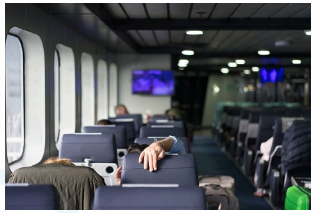
Co-funded by the Erasmus+ Programme of the European Union

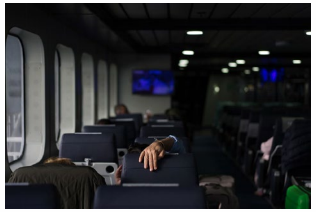


Automatic mode: The automatic mode of the cameras takes light references and adapts the variables to the existing light conditions, in order to obtain the best results in the photographic captures.

If the variables are not well calibrated, it is possible to find different scenarios such as overexposure, where the composition will be too bright, with an increase in brightness, or the opposite result, underexposure, where the light will lack the amount of illumination and a proliferation of shadows will be captured.


Overexposed


Well Exposed


Underexposed

1.3.2. Camera.

Co-funded by the Erasmus+ Programme of the European Union

Drones: Camera-equipped drones have similar patterns to the above. They are very useful work tools, these unmanned flying devices allow data to be obtained from the air.

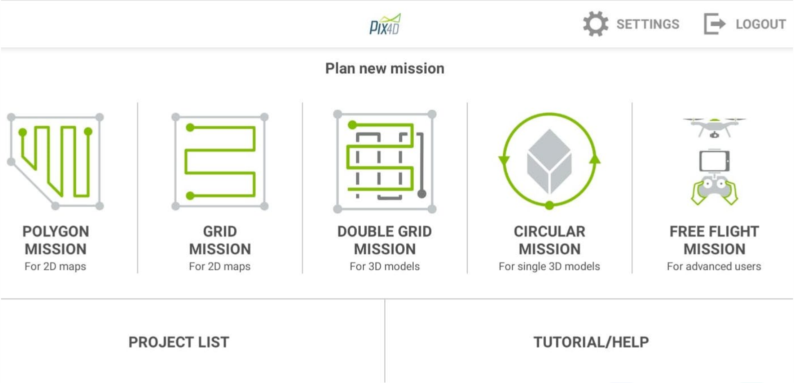
The main types of drones are fixed-wing and multi-rotor drones. Drones can carry an RGB, Thermal or Lidar camera, as well as a combination of aerial and terrestrial point clouds, for example, point clouds created by a terrestrial laser scanner and a photogrammetric cloud generated by a drone.

1.3.2. Camera.

Co-funded by the Erasmus+ Programme of the European Union

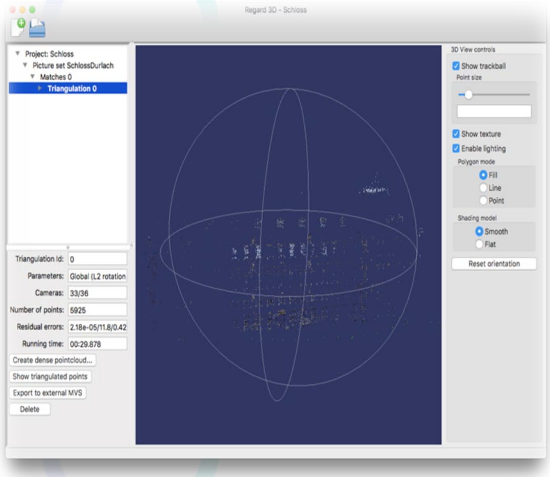
The drone can fly and take pictures with manual control of the controller, but there are programmes and applications for mobile devices such as tablets or smartphones to link the controller and the drone, serving as support for different types of flight missions.

Mission plans with selected and premeditated routes through a virtual map, where it is possible to choose the flight mode, altitude and amount of photographic captures desired, among other options.



1.3.3. Software.

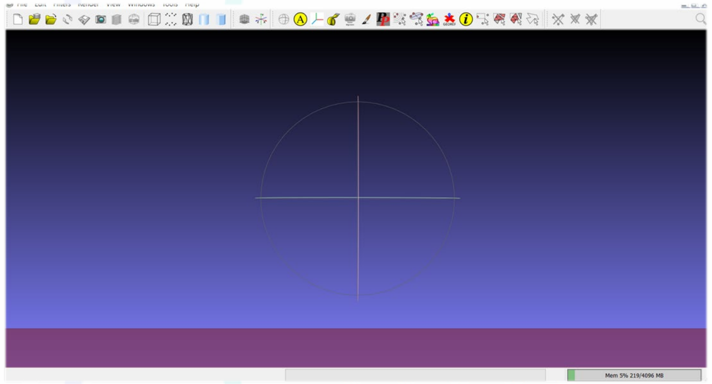
Co-funded by the
Erasmus+ Programme
of the European Union



Software: There are different types of software for assembling, managing and editing different types of content and 3D elements. Some of these programmes are specialised in aerial photogrammetry only or even allow the computation of data obtained by different photogrammetric techniques in conjunction with data digitised with laser scanners. Another type of existing software is the management and editing software, although the previous ones have basic tools to edit the obtained 3D results, these softwares have more options for editing and obtaining data.

1.3.3. Software.

Co-funded by the Erasmus+ Programme of the European Union



Post-processing software: After obtaining the three-dimensional resource by processing the information from the captured images, it is possible that the result obtained is not entirely satisfactory or that the programme we have used lacks a large number of advanced tools for managing and editing meshes or point clouds, so it is a good idea to post-process the three-dimensional resource, and we can obtain great results such as improving the texture, simplifying the point cloud, subjecting it to reordering or improving the texture.

Free programmes such as Meshlab help us to improve our three-dimensional resources to the maximum.

BIMVET3

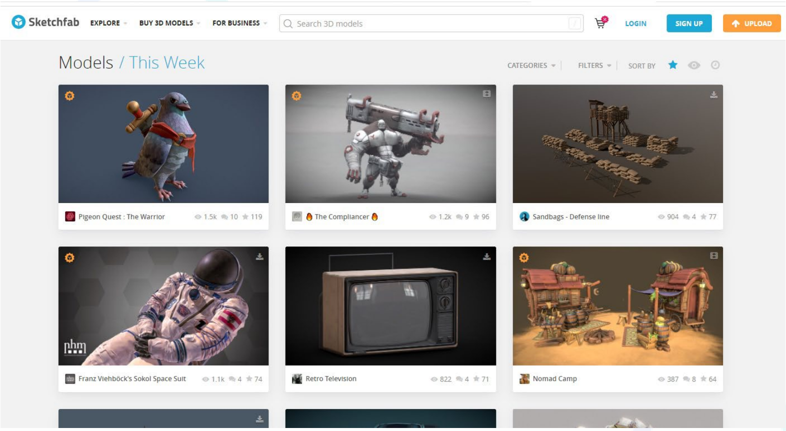
1.3.4. New Visualisation and DisseminationTechnologies.

Co-funded by the Erasmus+ Programme of the European Union

New visualisation and dissemination technologies Dissemination platforms, there are online platforms that allow the upload and visualisation of 3D elements of different types. These elements can be displayed on these platforms for multiple reasons, either for enjoyment, advertising or to show the services that can be offered, cultural and scientific dissemination, teaching...

Dissemination, photogrammetry in society. A large part of the photogrammetric processes have been automated thanks to new technologies, which has made it possible for it to be used by non-professional users, who practice this discipline as a hobby, creating a worldwide community.

Sketchfab



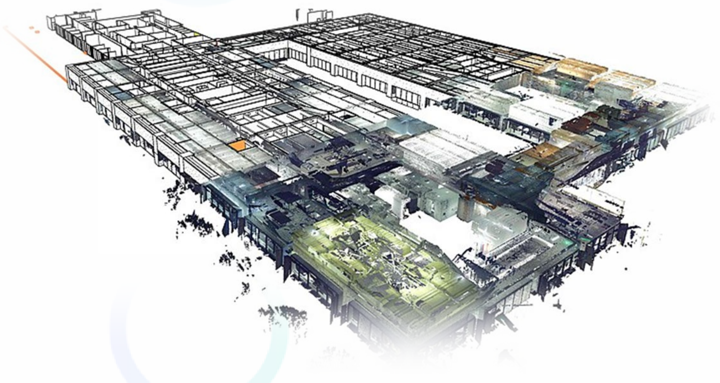
Click on the images to access their content

Bibliocad

2. Uses of Photogrammetry

2.1. Photogrammetry in BIM.

Co-funded by the Erasmus+ Programme of the European Union

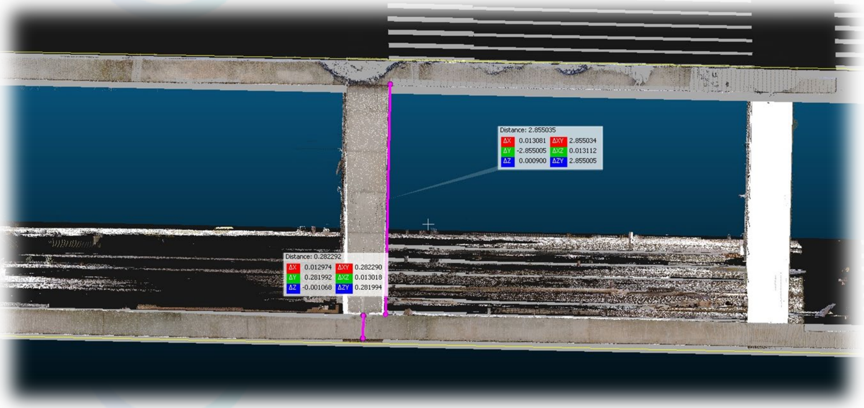


BIM: Photogrammetry can be linked to the BIM project from the Design phase through to the execution, construction control and later in inspections, renovations of the building in question or demolition.

From the beginning with photogrammetric studies on the ground, it allows measurements to be taken and ground studies to be applied. Subsequently in the control of works, the use of augmented reality for this and other uses, creating information that can be contrasted with the new captures of reality that are developed in different inspections to be compared with these first ones, in the same way the renovation processes are also very useful because thanks to the capture of point clouds, it allows you to model with an architectural program the built environment creating an "as build" model.

2.1.1. Modeling.

Co-funded by the Erasmus+ Programme of the European Union



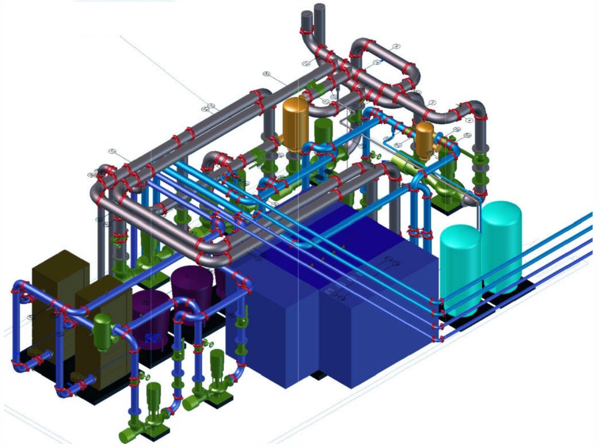
Modelling: Modern 3D modelling programmes specialised in architecture have drawing and editing tools similar to those used in CAD, which make it possible to carry out real three-dimensional surveys.

The capture of a point cloud of a building, or constructed area, together with the implementation of these programmes, makes it possible to create products such as updated planimetries with the measurements, dimensions and distribution of real spaces.

2.1.2. AR/VR.

Co-funded by the Erasmus+ Programme of the European Union

VR/AR: Within Virtual Reality and Augmented Reality, we must distinguish the different agents that together with photogrammetry make it possible: Physical part such as the reproduction support, which can vary according to the technology or use, and can be reproduced from a computer, tablet, smartphone or innovative stereoscopic lenses, there is another intangible part such as the software that is installed on these devices to offer the reproduction of the content.

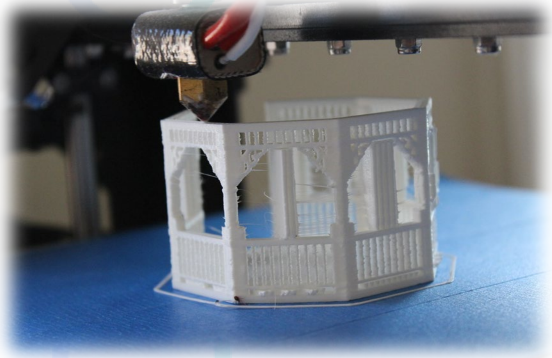


The raw existence of the point cloud or polygonal mesh from this makes it possible to reproduce it on any device, but this is usually completed with a three-dimensional model of the construction in order to be able to observe different elements or unplanned deviations. As well as allowing the control of the development of the works, this type of technology is widely used in piping systems.

These tools have established themselves as sustainable architectural tools as they do not require any environmental resources for their reproduction.

2.1.3. 3D Printing.

Co-funded by the Erasmus+ Programme of the European Union



3D Printing:

3D printing is an activity that is increasingly in demand in various sectors. In the construction sector it is possible to find 3D printing in different areas and with variable usability. By obtaining a polygonal mesh and exporting it in file formats compatible with 3D printers such as STL.

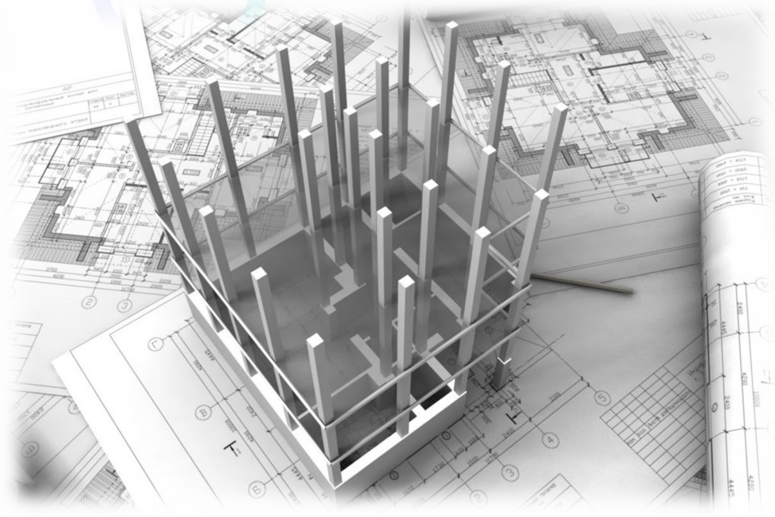
Projects: Research work on composites for concrete and construction materials.

Marketing: With the printing of models made of plastic materials or concrete.

Construction work: Printing of architectural elements, such as wall panels, ornaments and mouldings, among others.

2.1.4. New Build.

Co-funded by the Erasmus+ Programme of the European Union



New Build:

The application of photogrammetric science within BIM, in a new construction project, begins with the photogrammetric sweep of the terrain where the work is planned.

During the execution phase, the inclusion of photogrammetric processes can be very useful to eliminate imperfections such as column deflections or excess slab. This provides valuable first-hand information and is available to the foreman for reporting purposes.

The existence of photogrammetric information provides security, control and transparency.

2.1.5. Renovation.

Co-funded by the Erasmus+ Programme of the European Union

Renovation: Photogrammetry can be a reality capture technique of great importance during the renovation process of a building, since from obtaining point clouds and applying them in specialised architectural software such as Revit, it is possible to raise the new layouts and spaces of the property, being able to document all divergences on the existing 2D plans, allowing the elaboration of new ones.

In the case of the renovation of a historic building, digital documentation makes it possible to recover ornamental elements, original mouldings of the building, allowing, thanks to its three-dimensional capture, its subsequent replication, being able to use the 3D product, even for additive printing.

2.1.6. Demolition.

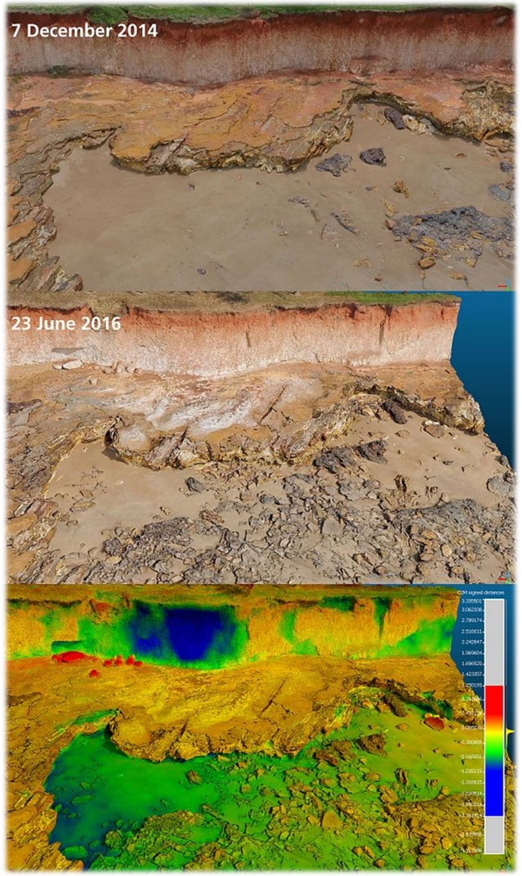
Co-funded by the Erasmus+ Programme of the European Union

Demolition: Demolition operations are subject to rigorous safety measures, with the creation of a BIM model "as build" a so-called digital twin can be created. The digital twin, obtained through photogrammetric documentation, is a valuable tool that can generate simulations, to manage and develop the demolition plan in the most accurate and adaptable way.

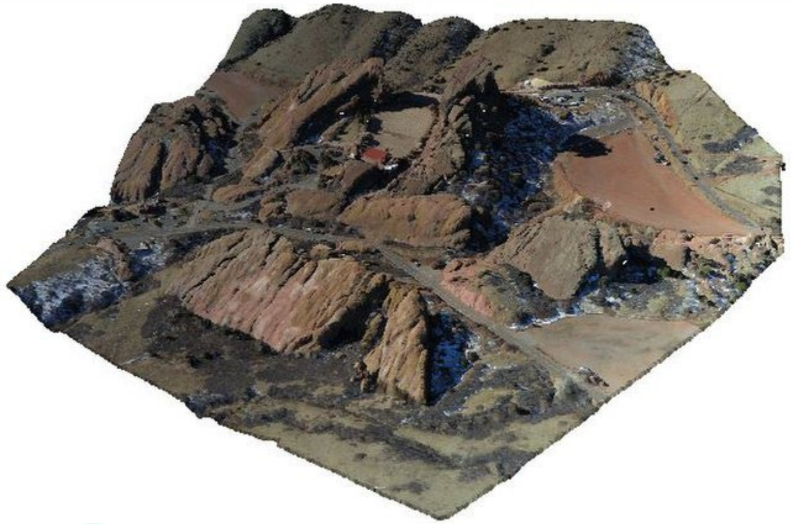
It also allows for the generation of an appropriate waste management plan.

2.2. Geotechnical studies (GIS).

Co-funded by the Erasmus+ Programme of the European Union



The application of photogrammetry to geotechnical studies is closely linked, as it was created for cartography from the very beginning. Currently, the capture of aerial images taken by drones allows for a total reconstruction of the terrain and territory used for the control of protected areas, geological studies or land and property subdivision.

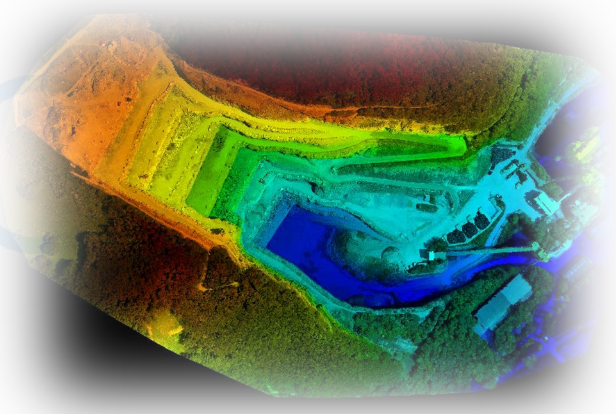


2.2. Geotechnical studies (GIS).

Co-funded by the Erasmus+ Programme of the European Union

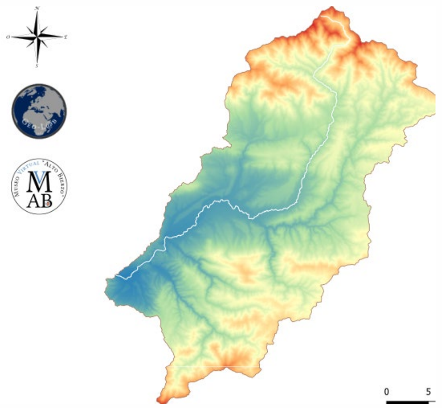
DSM:

Digital surface model is a three-dimensional model with numerous values. It includes all vegetation, relief or existing infrastructures, therefore all biotic and anthropic elements.



DTM:

Digital Terrain Model is a three-dimensional model with concise values. Where all information not refer to the natural relief of the bare terrain, without vegetation or other natural or anthropic elements, is eliminated.



2.3. Videogames.

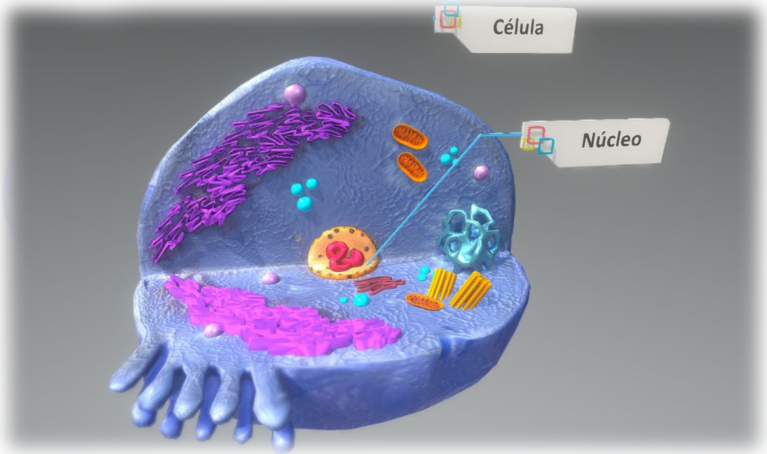
Co-funded by the Erasmus+ Programme of the European Union

The video game industry also benefits from this methodology, which allows photorealistic results to be imported into their creations. Sagas such as Assasins Creed are some of the projects where photogrammetric methods have been used to obtain different objects, textures or characters.

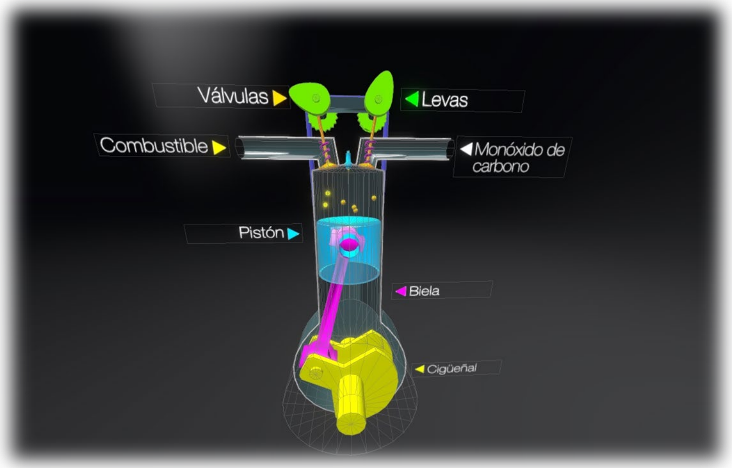
2.4. Teaching.

Co-funded by the Erasmus+ Programme of the European Union

Numerous studies advocate the use of three-dimensional elements within education at all levels from secondary school levels, through architecture and art history to a medical school where an animated heart can be observed in operation or in tertiary education where the parts of a car engine are broken down.



Click on the images to access their 3D content.



2.5. Cultural Heritage

Co-funded by the Erasmus+ Programme of the European Union

It is used for the same uses mentioned above, whether for control, documentation for study or dissemination as an element of publicity and enjoyment. Given that heritage is something that needs to be analysed and controlled in order to preserve it, study it and finally share it with society as a whole for its use and enjoyment, platforms such as Sketchfab provide a free repository and visualisation service and serve as powerful dissemination tools.

Click on the images to access their 3D content.

3. ANNEXES:

Co-funded by the Erasmus+ Programme of the European Union

- **Digital photogrammetry:** Three-dimensional documentation technique based on the computation of 2D values contained in photographs.
- **Drone:** Unmanned aerial element, operated from the ground.
- **Fixed Wing: A** type of drone whose main flying element is the possession of a large wing.
- **Multi-rotor: A** type of drone equipped with propellers that rotate in different directions to fly the device.
- **Homologous Points:** Positioned and repeated elements in photographs that are endowed with coordinates (X,Y,Z) and represented.
- **Point cloud:** A collection of vertices represented by homologous points that mimic the shape and volume of the captured element.
- **Polygon mesh**: Surface created by joining the vertices of the point cloud.
- **Lens:** Circular glass attached to the lens that lets light into the camera.
- **Focal Length:** Distance measured in mm between the camera lens and the sensor, usually engraved on the lens barrel.
- **Wide Angle Lens:** Lens with short focal length and wide field of view.
- **Fisheye Lens:** A wide-angle lens that takes 180° of photography and uses its large visual distortion to create desired effects in photography.
- **Zoom lens:** Lenses that allow variation of focal length through the use of physical zoom, the most widely used lenses in the world.

3. ANNEXES:

Co-funded by the Erasmus+ Programme of the European Union

- **Fixed lens:** Lens that allows only one focal field and therefore cannot make physical zoom adjustments.
- **ISO:** Adjustment option that allows the brightness of the light to be increased in the dark, by altering the light sensor.
- **Camera Aperture**: Lens opening and closing adjustment option used to regulate the light passing through the lens.
- **Shutter speed:** Adjustment option on the mechanism that allows opening and closing the shutter at desired times and repetitions..
- **Augmented Reality:** Technologies that add and reproduce virtual three-dimensional information about reality through the use of mobile devices such as tablets or smartphones, among others.
- **Virtual Reality:** Technologies that favour an immersive experience of object simulation and a three-dimensional world.
- **3D Printing:** Technique of creating elements using a 3D printer by loading a digital design and obtaining the physical design.
- **BIM:** A methodology consisting of a set of processes used in construction and engineering through the use of a shared virtual model to monitor construction work.
- **Digital Twin:** Digital representation of a building, with the visual and physical characteristics of the original.
- **Geotechnics:** Discipline that uses scientific methods for the interpretation and knowledge of soils.
- **MDS:** Three-dimensional model that processes all the elements that make up the captured information.
- **DTM**: A three-dimensional model that processes and focuses its analysis on the bare earth's surface.

6- Deliverables:

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

7- What we have learned:

The student has learnt the inner workings of photogrammetry, the relationship of homologous points, point clouds and polygonal meshes, as well as the different photogrammetric capture tools and their internal functions and variables.

The student has learnt about the use of the photogrammetric technique in construction outside of it, as well as its different uses and utilities, on site, control and dissemination.

Co-funded by the Erasmus+ Programme of the European Union

BIMVET3