الجمهورية الجزائرية الديمقراطية الشعبية
People's Democratic Republic of Algeria
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Ministry of Higher Education and Scientific Research
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Faculty of Science and Technology Department
of Civil Engineering and public works

Thesis for obtaining the Master's degree
Sector: CIVIL ENGINEERING
Specialty: VOA
Theme:

CALCULATION OF THE VOLUME BY TERRESTRIAL PHOTOGRAMMETRY

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SUSTAINED ON: 03/07/2021

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SESSION YEAR 2020/2021

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Université Belhadj Bouchaib d'Ain-Temouchent
Faculté des Sciences et de la Technologie
Département de Génie Civil et travaux publics

Mémoire pour l'Obtention du diplôme de Master
Filière : GENIE CIVIL
Spécialité : VOA
Thème :

CALCUL DE VOLUME PAR PHOTOGRAMMETRIE TERRESTRE

PRESENTE PAR :

- MANSOURI ROUMAISSAA
- BORSLA NESRINE

SOUTENU LE : 03/07/2021

DEVANT LE JURY COMPOSE DE :

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ANNÉE UNIVERSITAIRE 2020/2021

CALCULATION OF THE VOLUME BY TERRESTRIAL PHOTOGRAMMETRY

ACKNOWLEDGMENTS

We overwhelmingly grateful to Allah for giving us such empowerment that provides an impetus of passion and perseverance to achieve our target. My deepest gratitude and thanks go to our supervisor Mr. KADDOUR hakim for his help, encouragement, and guidance, thank you for all what did you for us.

DEDICATIONS:

الى من احمل اسمه بكل افتخار و علمني العطاء دون انتظار كل له الله بالهبة والوقار وابقاه

فوق رؤوسنا ذخرا وا كبار

ابي الغالي

الى اول من نطق باسمها اللسان وترتاح عند رؤيتها العينان الى أحلى اسم تطرب له الاذان

بعد رب العزة والنبي العدنان الى من علمتني خطى الحب وأدخلت السرور الى قلبي الى

ماضي وحاضري و مستقبلي

امي الغالية

الى بضعة من امي الى من يشاركني بعض همي الى سندي في الحياة ال من بوجودهم ا كتسب

القوة و المحبة ولولاهم ما عرفت معنى الاخوة

* اخوتي*

الى كل من يسعهم قلبي ولم تسعهم ورقتي

الى كل من دفعني في الاستمرار وساهم في نجاحي

الى احبتي واصدقائي ورفقاء دربي

الى كل هؤلاء

اهدي ثمرة جهدي

TABLE OF CONTENTS :

CHAPTER II: PHOTOGRAMMETRY SYSTEM

CHAPTER III : METHODOLOGY

CHAPTER IV : APPLICATION

LIST OF FIGURES:

LIST OF TABLES :

ABSTRACT :

Knowing the volume of objects represents important information in various fields, in civil engineering.

In the practical stage, the volume calculation is usually carried out using expensive instruments such as topographic devices.

The objective of this research is to propose a fast, less expensive and precise alternative solution using terrestrial photogrammetry techniques.

Indeed, the tests carried out on laboratory induced to saucerful results, the accuracy reaches 99% of the real volume by using only an ordinary mobile phone camera.

Keywords: Terrestriel photogrammetry; 3D reconstruction, volume.

RESUME :

Connaitre le volume d'objet représente une information importante dans divers domaines notamment en génie civil. Sur terrain, le calcul de volume s’effectue généralement par des instruments onéreux comme les appareils topographiques.

L’objectif du sujet est de proposé une solution alternative rapide, moins couteuse et précise et ceci par l’utilisation de la photogrammétrie terrestre.

En effet Les tests effectuées au niveau du laboratoire en induit a des résultats dont l'exactitude a atteint 99% de volume réel et ceci par l'utilisation d'un téléphone cellulaire ordinaire seulement pour la reconstitution 3D des objets en question.

Mots-clés : Photogrammétrie terrestre ; reconstitution 3D, volume.

ملخص:

معرفة حجم الأشياء يمثل معلومة مهمة في تطبيقات عدة لاسيما في الهندسة المدنية. حيث تتم عملية قياس الأحجام باستخدام أدوات باهظة الثمن مثل الأجهزة الطبوغرافية.

الهدف من هذه الرسالة هو اقتراح حل بديل دقيق، سريع وأقل تكلفة ذلك باستخدام القياس التصويري الأرضي. وبالفعل وباستخدامنا لكاميرا لهاتف خلوي العادي بعد معايرتها ومعالجة الصور الملتقطة تم إعادة بناء مجسم رقمي ثلاثي الأبعاد لأشياء المعنية.

الاختبارات التي تم إجراؤها على مستوى المختبر وصلت دقة النتائج فيها إلى 99٪ من الحجم الحقيقي.

الكلمات المفتاحية: المسح التصويري الأرضي؛ إعادة بناء ثلاثية الأبعاد، الحجم.

GENERAL INTRODUCTION:

In order to measure the cubature for the embankments and cuttings, topographic operations are necessary, instruments were used such as total stations or tacheometer or LIDAR (3D scanner).

Inside buildings, the use of a laser meter equipped with a volume calculation program remains was used widely.

In laboratories, Knowing the volume of objects requires the use of graduated cylinders or metric measurements of lengths and widths is the most common operation.

Figure 1 : Exemple of Instruments for calculating volume. [1]

In addition, each of the methods used presents major disadvantage. Namely; the high cost of topographic instruments; or the limitation of measurements on certain objects whose geometry must be simple for the cases discussed above.

In order to remove these problems, Photogrammetry presents currently a very interesting alternative as a new technology at lower cost with remarkable measurement quality.

Its scope of application is increasing every day, in particular terrestrial photogrammetry or close-range photogrammetry.

Better yet, it is possible to scale these objects in order to perform any geometric measurement on the reconstructed objects.

On the other hand, terrestrial photogrammetry is based on a theoretical basis essential to master as well as the use of specific software on machines suitable for such image processing.

In addition, the photo acquisition methodology must comply with certain rules concerning the configuration of the device used for the shooting technique.

All these concepts are treated in our thesis in the first, second and third chapters.

Questioned will be answered such as:

- What are the theoretical concepts related to this new technology?
- What are the procurement methods to have such a product?
- What are the dedicated cameras for this job?

The fourth chapter is devoted to the application carried out with the approach followed on the photomodeler software in order to calculate the volume of certain objects of different natures and aggregates.

CHAPTER I :

BASIC CONCEPT OF TERRESTRIAL PHOTOGRAMMETRY

I. DEFINITION:

Photogrammetry is art of science based on technology with more than a century of history and development. [2]
Anything that has a geometric link with drawing and measurements in images, on lines, columns, radiometry = precisely locate and geometrically restore objects from images [3].

Photogrammetry is a technique to measure position, size and shape of any physical object, using two dimensional photographic images or, using digital images of the object with the availability of digital cameras, storage media, computer hardware and software at affordable cost, there is a dramatic increase in the use of digital photogrammetry in fields that requires precise measurements. [4]

Photogrammetry is also being categorized as aerial and terrestrial photogrammetry. The areal photogrammetry has been widely used in topographic mapping for land development and exploration for natural resources. [5]
On other hand, the terrestrial photogrammetry is commonly used at ground level for small-scale surveying, manufacturing and industrial applications. There are also researchers that defined the terrestrial photogrammetry as close-range photogrammetry. [6]

II. HISTORY:

Photogrammetry is a technique that emerged very quickly following the invention of photography in the 19th century.In the last centuries, different painters had studied perspective using simple optical devices. [7]

The idea was already to fix on paper an image as neutral, objective and conform to reality as possible and to reconstruct the shape, dimensions and position of an object from perspectives Subsequently, the use of images to measure the distances of different objects was only a simple re-use of topography techniques, such as triangulation and intersection. And as the showed it well, the envisaged applications were initially of the military type:

how to adjust the fire of a cannon, how to map an enemy stronghold without approaching it, etc. [8]

In 1859 that the French colonel A. Laussedat presented to the Academy of Sciences, a method determination of coordinates of points based on a calculation of spatial intersection from a couple photos of the object. At the same time, the German architect A. Moldenhauer, to whom we owe the term of photogrammetry, successfully uses these techniques in large-scale architectural works. Numerous technical and theoretical advances have allowed, from the beginning of the 20th century, this new science to evolve rapidly: stereophotogrammetry developed by C. Pulfrich (1901), the definition of principles for a rational implementation of optic-mechanical retaliators by O. von Gruber… Currently, the development of the means of calculations is such that they allow to process more and more data, with increasingly complete algorithms. [9]

Photogrammetry has also undergone an evolution whose history we wish to recall here:

Figure 2 : Analog renderer photogrammetry [10]

Analog photogrammetry: was used for decades: it presented physical constraints (angular and linear) of relative and absolute orientation due to optic-mechanical equipment. [9]

Figure 3 : Analytical renderer Photogrammetry [11]

Analytical photogrammetry: eliminates the demands of physical analogy; the model is produced digitally, always from photographs, their geometry being most often known. Today, digital images are supplanting photography. The pixel attempts to succeed the grain of silver as a unit of measurement. [9]

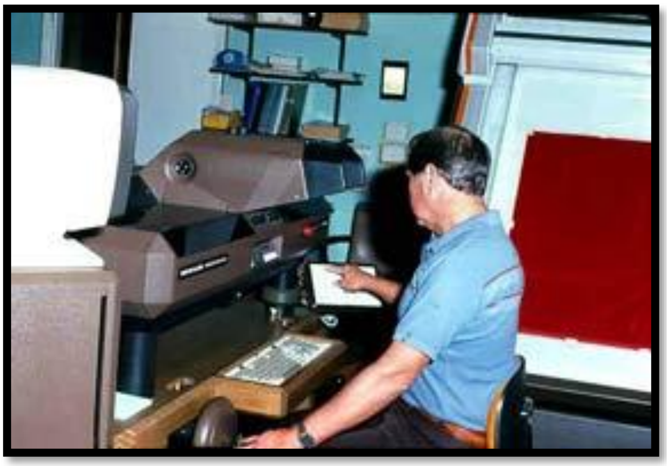


Figure 4 : Digital photogrammetry [11]

Digital photogrammetry works according to the principle of image correlation. Correlation is the automatic recognition of homologous pixels on a defined surface. It is always essential that the photographs exhibit similar geometric and photographic qualities. [7]

These characteristics are guaranteed in the case of images taken with metric chambers equipped with DTC6 matrices. At this stage, a virtual stereoscopic observation will allow the determination of XYZ points and the creation of digital terrain models, either manually by merging and entering characteristic points of the object, or automatically by correlating them. images following a programmed fixed mesh. [12]

III.CLOSE RANGE PHOTOGRAMMETRY(CRP) :

The term CRP is defined as a technique for measuring an object at a distance of less than about 100 m and the camera is positioned close to the object [13].
A number of researchers advocate that 300 m as maximum limit for CRP [4].
While minimum distance is a fraction of a millimeter CRP. [14]
Recently, with the image is captured and stored in digital format, the close-range photogrammetry is commonly known as DCRP. DCRP is a method where the three-dimensional measurements are made from two dimensional digital images taken on one object. In general, digital images are taken from an object from at least two camera positions. From each camera position, there is a line that runs from each point on the object to the perspective center of the camera. Using a principle of triangulation, the point of intersection between the different lines of sight for particular points is determined mathematically to identify the spatial or three-dimensional locations of the object points. [15]

In civil engineering the DCRP techniques is widely applied in various applications such as to monitor and measure soil erosion; to study beach profile changes; to monitor and evaluate progress of construction project; to monitor soil excavation activities at construction site for measurements in laboratory experiments on construction materials. [15]

IV. THE USES OF PHOTOGRAMMETRY:

Photogrammetry uses photographic cameras to obtain information about the 3D world. The basic principle of photogrammetric measurement is straightforward: recording a light ray in a photographic image corresponds to observing a direction from the camera to the 3D scene point where the light was reflected or emitted. From this relation, procedures have been derived to orient cameras relative to each other or relative to a 3D object coordinate frame and to reconstruct unknown 3D objects through triangulation. Provides a compact, gentle introduction to the fundamental geometric relations that underly image-based 3D measurement. [16]
Measure in photos means measure without a physical contact to the object. Therefore, if you have very smooth objects like liquids, sand or clouds, photogrammetry will be the tool of choice. [16]

All kind of fast-moving objects will be measured with photogrammetry. For instance, these may be running or flying animals or waves. In industry, highspeed cameras with simultaneous activation are used to get data about deformation processes. [17]

V. CLASS OF PHOTOGRAMMETRIC RESTITUTTION:

1. Lineal photogrammetric restitution:

In this case, lineal plans are elaborated by means of the orthogonal projection of the structure photographed onto a previously defined reference plane. The position of the used reference plane has to be known in the coordinates system used for the terrestrial control. Usually, in the restitution of facades, are used vertical reference planes parallel to the main direction of the structure surface. [18] As an example of this type of restitution, Figure 1 shows a general survey of Milla Church, in Mérida, Venezuela, where the plotting scale was 1/100. This survey was done for inventory purposes. [18]

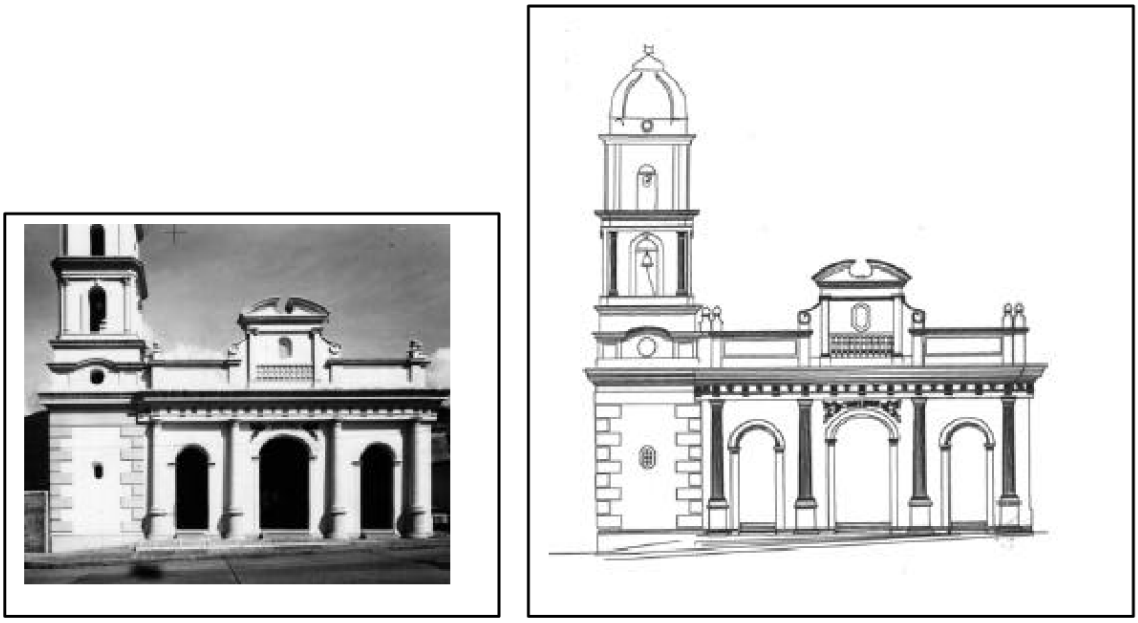


Figure 5 :Lineal photogrammetric restitution [19]

2. Digital photogrammetric restitution:

Through digital restitution, the coordinates X, Y, Z of every point representing the building is determined. In this case no reference plane is used, but a coordinates reference system, in which all measurements are performed. When using analogue plotting instruments, as in our case, digital restitution is done by means of adapting analogue to digital converters to the instrument,and by means of an electronic interface the digital output coordinates are sent to the computer (PC) where they are processed by a CAD package, as AutoCAD for example, in order to produce a digital drawing. Figures 2 and 3 shows an example of a digital restitution. This is a detailed survey of the Congress building in Caracas, Venezuela, in which all features of the structure have to be represented in a 3-D way using AutoCAD, in order to create files with all the detailed geometrical information. The plotting scale used was 1/25. [20]

3. Lineal restitution superimposed on rectified digital images:

As the terrestrial photogrammetry includes works of restitution of monuments of historical interest in some projects, it was needed to do the restitution of faces which are represented only by its contour or by the limits that defines the construction. Due to the simplicity of then, but their richness in texture, they deserve a better representation than the lineal one. [7]

With the advance in technology, we can make use of powerful computers, CAD and digital image editing or processing programs and peripherals as scanners and plotters of photographical quality, to make possible today, the union between the classical techniques and the photographical rectification, in order to offer a product similar to a picture in their general aspect, but with the geometrical characteristics of a plane. To achieve this kind of geometrically correct images, two classes of data have to be jointed: The linear map obtained from the restitution of photographs, and the digital image of that pictures. [13]

To obtain a digital image, there are two means: directly, using a digital camera, or by the use of a scanner; this one is still preferable to the digital camera, because we can have a greater number of pixels if we scan an enlargement, so the final image can be plotted at a scale 1:50 or 1:25 without loss of detail. [13]

The processing of the image is made up in three forms. firstly, it has to receive pictorial improvements, as contrast, hue and luminosity. With the image improved, the rectification is made; sometimes, in very simple faces, a rotation and scale will be enough. The third operation consists of and eliminate o image the elements that does not belong to the face. [13]

Figure 6 : Use of small format aerial photography [19]

The Institute of Photogrammetry of the University of Los Andes, had under his responsibility to make the aerial and terrestrial photogrammetrically surveying and the photointerpretation of a zone occupied by the ruins of an ancient mission's town, founded in 1620, and abandoned two hundred years ago. To achieve this objective, techniques of rectified digitized fronts and digital orthophoto maps from zones of archaeological interest were carried out. shows an example of application of this technique. [18]

4. Use of small format aerial photography:

The Laboratory of Photogrammetry of the Forestry Sciences Faculty, lent the camera used in this mission. It was a Hasseblad 553 with a lens of 40mm focal length, using Kodak Vericolor film, and equipped with an intervalometer home-made. The camera mounting, also of this laboratory, was of the lateral luggage door type, made to fit in a Cessna 182 aircraft. The fact of flight over a closed zone with strong winds, obliged to make the photographs a little early in the morning (10:00 a.m.), with the disadvantage of have a disturbing shadow in the ruins. Another consecuence of topography of the place was that the flight had to be made against slope. A total of two strips with 5 pictures each was taken of the town of San Antonio de Mucuño, at 2000 m height and a scale 1/15000. The restitution of the models was superimposed over the scanned pictures rectified. [18]

VI. IMAGE ACQUISITION PLATFORMS:

In photogrammetry, the platforms that can accommodate the acquisition systems range from the satellite in orbit at very high altitude to the operator in the field. The choice of platform depends of course on the application, the scale of work and the budget. [21]

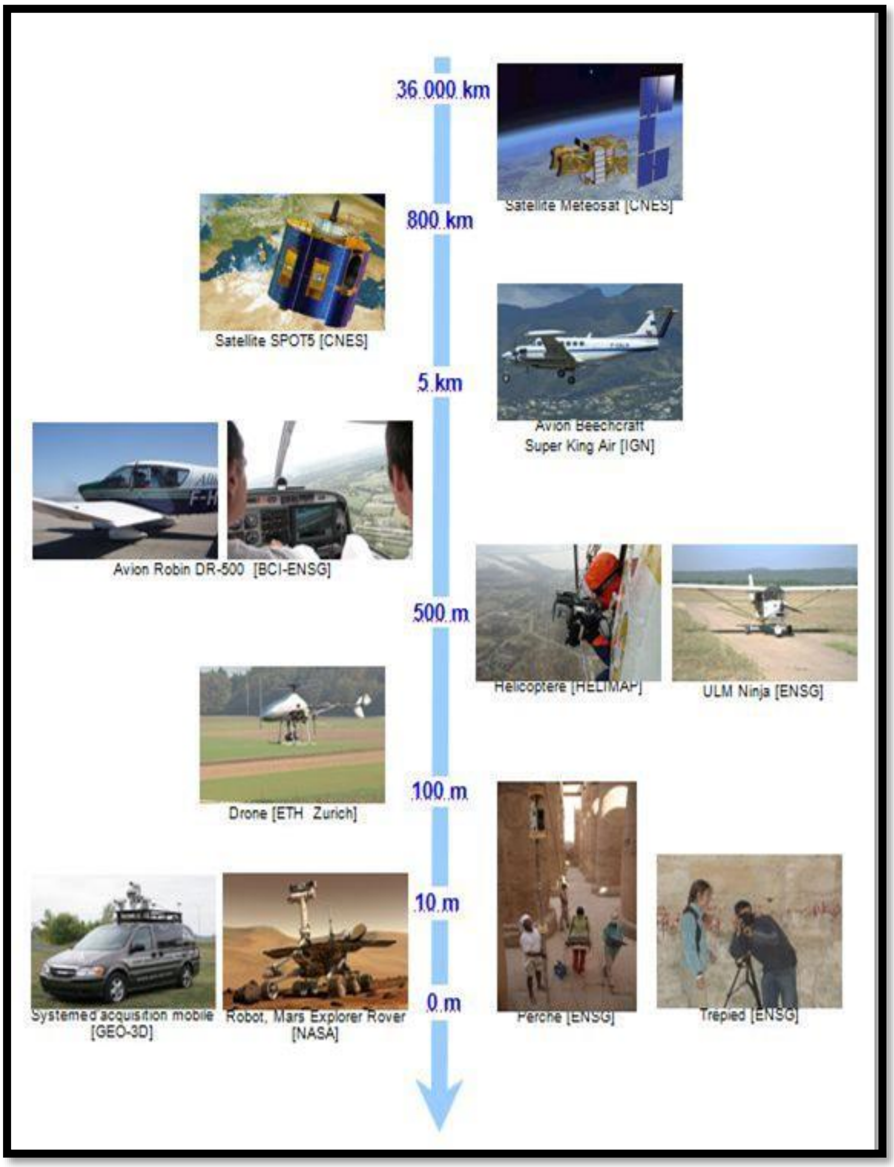


Figure 7 : Different plate-forms according to the altitude of shooting [22]

1. Spatial:

Since the 1960s, Earth observation satellites have provided resolution images ranging from kilometers to tens of centimeters from array sensors scanning the Earth's surface. The image is formed as the satellite advances along its path and a given sensor offers a single point of view. [5]

Figure 8: Landsat 8 satellite [23]

To use spatial images photogrammetrically and therefore have different points of view, several possibilities are possible:

- the acquisition system includes two cameras aiming in two different directions: the HRS instrument of the SPOT 5 satellite is for example made up of two front sight (+ 20 °) and rear sight (-20 °) sensors;
- the satellite is "agile", it is able to modify the direction of sight and point forwards then backwards;
- you have to wait for the satellite to come back on a close trajectory. [5]

2. Aerial:

This is the main activity sector of photogrammetry even if very high-resolution satellites can more and more claim to compete with airborne acquisitions. [24]

Obtaining stereoscopic images is done naturally by adapting the acquisition rate so that two successive images have a common part. For classic large and medium-scale mapping applications, airplanes are the preferred vector: a camera is placed on board so as to aim at the surface of the Earth, possibly through a window. Depending on the model of the aircraft and in particular its ability to be pressurized, the flight altitudes can vary from a few hundred meters to around 10 kilometers. These depend on the characteristics of the camera and the images as we will see later. [24]

For even finer applications, it may be interesting to use other platforms, such as:

the helicopter, which makes it possible to reach environments that are more difficult to access, to work at higher resolution in smaller areas: study of landslides, avalanche monitoring, modeling of dams, etc. The drone, which is an unmanned, light aircraft, often used when it is difficult or dangerous to get to the area, for very small site . [24]

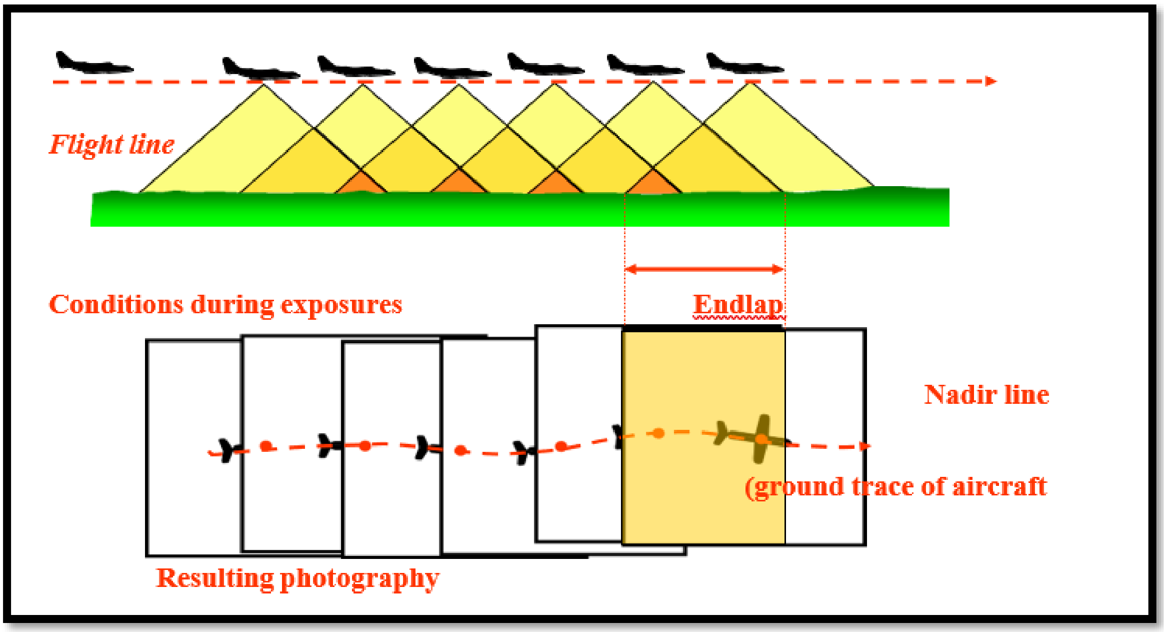


Figure 9 :Photographic coverage along a flight strip [25]

3. Earthly:

Everything that is not accessible from the sky (facades, interiors) is intended to be treated by land methods. Stereoscopy is obtained by simply moving the photographer or by the joint use of two cameras. Currently, the applications of terrestrial photogrammetry are very varied: heritage conservation, monitoring of engineering structures, exploration of dangerous or inaccessible areas, industry, street mapping ... Mobile acquisition systems also allow automation the photogrammetric survey of the arteries.

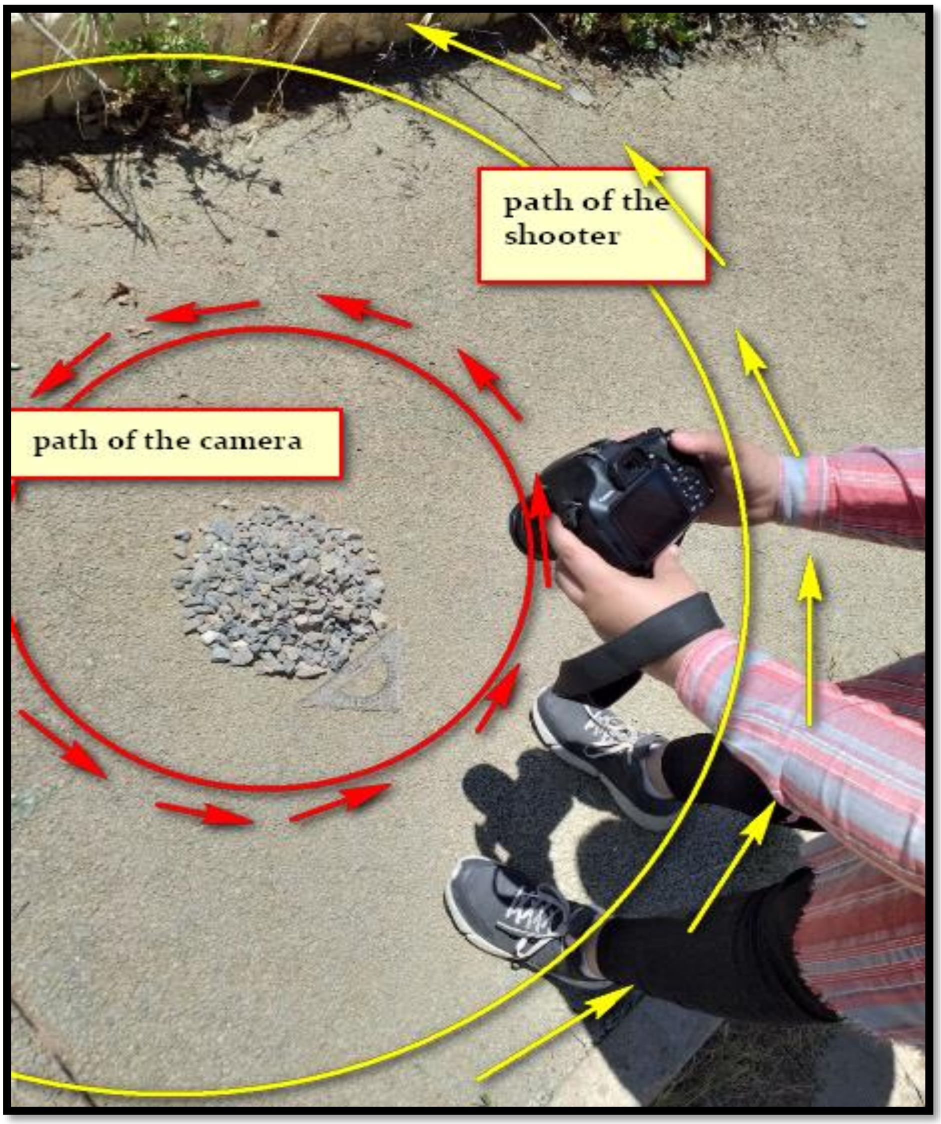


Figure 10 : Close range photogrammetry

VII. THE CATEGORIES OF PHOTOGRAMMETRY:

In CRP, the object's distance in space is less than 300 meters.

Photogrammetry can be categorized in several ways:

• By the position of the camera and distance from the object:

- Aerial photogrammetry: processing of aerial photographs, h> 300 m;
- Terrestrial photogrammetry: measurements from a fixed terrestrial location;
- Short range photogrammetry: imaging distance d <300 m;
- Macro photogrammetry: image scale> 1 (microscopic imaging);
- Mobile mapping: data acquisition from moving vehicles, <100 m. [6]

• By number of measurement images:

- Photogrammetry of a single image: single image processing, single-tracing, rectification, ortho-photos. [6]

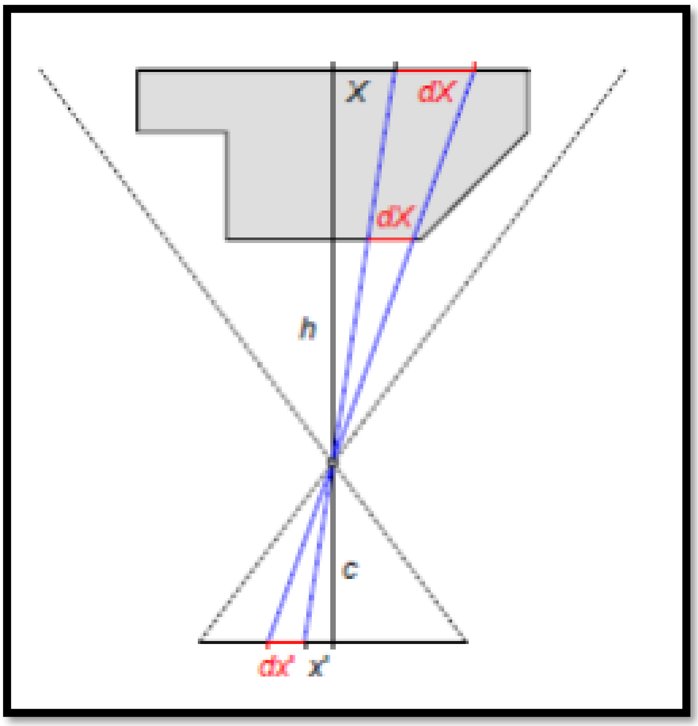


Figure 11 :Unique image acquisition

VIII. BENEFITS & DRAWBACKS OF PHOTOGRAMMETRY:

the Benefits of photogrammetry over standard surveying and mapping methods are as follows:

1. While capturing the Aerial photographs, photogrammetry produces an actual & permanent photographic record of a particular condition that exists while capturing images. Since the record has metric properties, it's not only a pictorial record, but also it is an accurate, measured record. [27]

2. For information that has to be re-surveyed or re-evaluated, there is no need to perform any expensive fieldwork. The same images we can measure again and can get new information in a very convenient manner. We can quickly remedy the missing information, such as inadequate offsets for cross-sections. [27]

3. It provides a wide mapped area so other line studies can perform with the corresponding data source more efficiently than other traditional methods.

Photogrammetry presents a broad view of the project field, by classifying both topographic and cultural features. [27]

4. It is useful in any locations that are difficult, unsafe, or impossible to access. Photogrammetry is an ideal surveying method for toxic areas where fieldwork may negotiate the safety of the surveying crew. [27]

5. A remarkable benefit of photogrammetry is that the road surveys can work without disturbing the traffic by closing lanes, or endanger the field team. Once it captures the roads the analysis of road features, including elevation data, we can do it in the office, not in the actual field. [27]

6. The coordinates of each point in the mapping field can determine with no additional efforts or cost. [27]

7. The aerial images are useful for conveying or describing information to the public, State, including Federal agencies, as well as to other divisions of transportation. [27]

CHAPTER II: PHOTOGRAMMETRY SYSTEM

I. THE PRINCIPE OF PHOTOGRAMMETRY:

The fundamental principle used by photogrammetry is triangulation. By taking photographs from at least two different locations, so-called "lines of sight" can be developed from each camera to points on the object. These lines of sight (sometimes called rays owing to their optical nature) are mathematically intersected to produce the 3-dimensional coordinates of the points of interest. Triangulation is also the principle used by theodolites for coordinate measurement. If you are familiar with these instruments, you will find many similarities (and some differences) between photogrammetry and theodolites. Even closer to home, triangulation is also the way your two eyes work together to gauge distance (called depth perception). [28]

This primer is separated into two parts. Photography describes the photographic principles involved in photogrammetry, while Metrology describes the techniques for producing 3-dimensional coordinates from two-dimensional photographs.

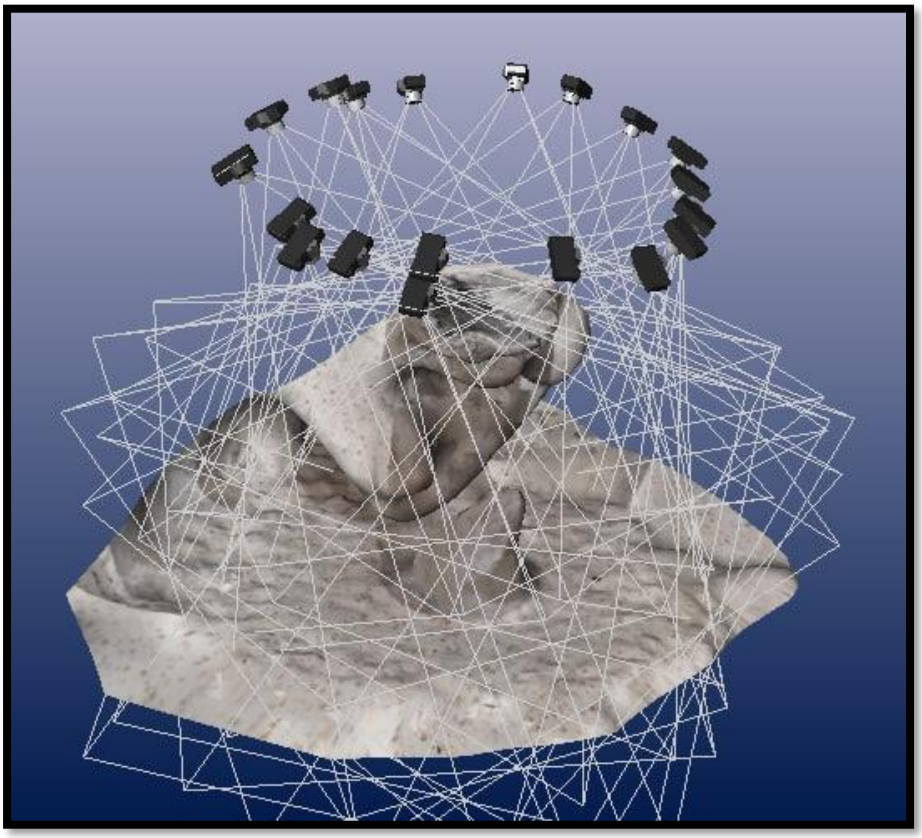


Figure 12 : Recovery Princip in close range photogrammetry [28]

II. WHAT DOES PIXEL MEAN:

A pixel is the smallest unit of a digital image or graphic that can be displayed and represented on a digital display device.

A pixel is the basic logical unit in digital graphics. Pixels are combined to form a complete image, video, text, or any visible thing on a computer display.

A pixel is also known as a picture element (pix = picture, el = element).

1. Explains Pixel

A pixel is represented by a dot or square on a computer monitor display screen. Pixels are the basic building blocks of a digital image or display and are created using geometric coordinates. [29]

Depending on the graphics card and display monitor, the quantity, size and color combination of pixels varies and is measured in terms of the display resolution. For example, a computer with a display resolution of 1280 x 768 will produce a maximum of 98,3040 pixels on a display screen. The pixel resolution spread also determines the quality of display; more pixels per inch of monitor screen yields better image results. For example, a 2.1 megapixels picture contains 2,073,600 pixels since it has a resolution of 1920 x 1080. [29]

The physical size of a pixel varies, depending on the resolution of the display. It will be equal to the size of the dot pitch if the display is set to its maximum resolution, and will be larger if the resolution is lower since each pixel will use more dots. Because of that, individual pixels may become visible, leading to a blocky and chunky image defined as “pixelated”. Pixels are uniformly arranged in a two-dimensional grid, although some different sampling patterns are available. [29]

Each pixel has a unique logical address, a size of eight bits or more and, in most high-end display devices, the ability to project millions of different colors. [29]

In the common 24-bit color systems used for nearly all PC monitors and smartphone displays, three bytes are allocated, one for each color of the RGB scale, leading to a total of 16,777,216 color variations. A 30-bit deep color system allocates 10 bits each of red, green, and blue for a total of 1.073 billion color variations. [29]

However, since the human eye cannot discriminate more than ten million colors, more color variations do not necessarily add more detail, and may even lead to color banding issues. [29]

III. DIFFERENCE BETWEEN PHOTOGRAMMETRY AND MAP:

A map is an orthographic view, which shows every object as if from directly above it.

whereas even a perfect vertical air photo is a perspective view from a central point.

[30]

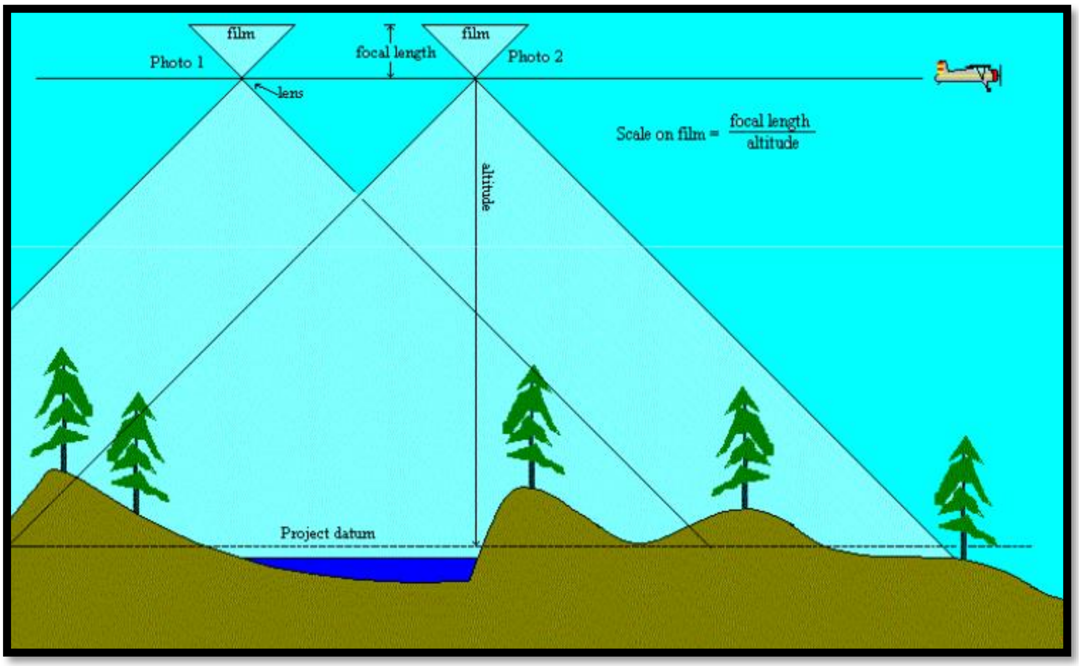
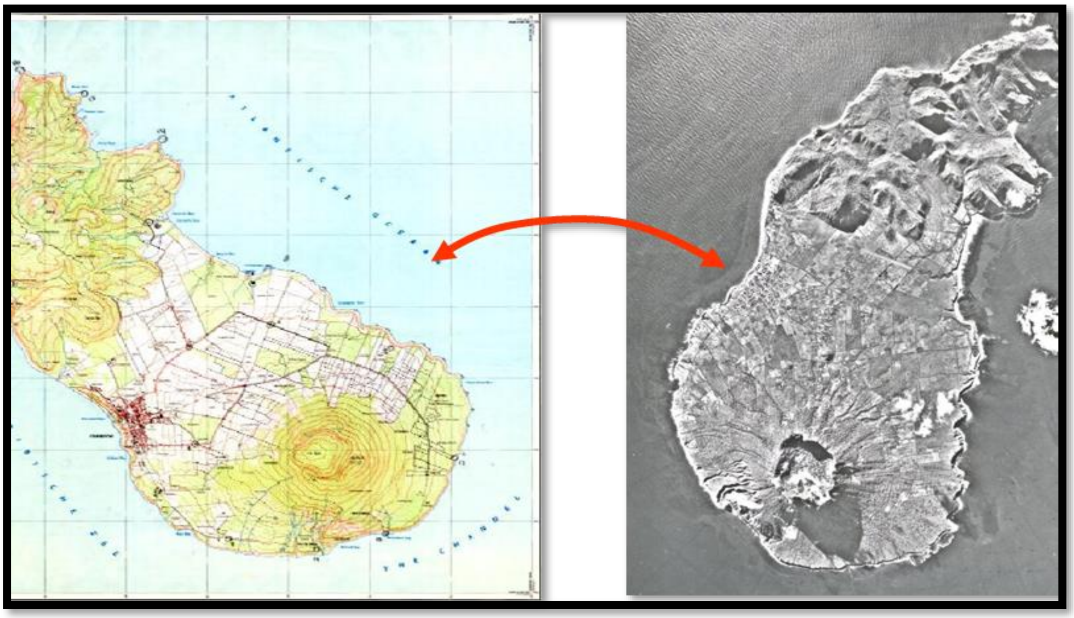


Figure 13 : Photogrammetry in aerial photography for a map. [31]

1. Difference between map and photo:



2.

Figure 14 : Topographic map (on left) Aerial photograph (on right). [31]

Table 1 Diffrence between map and photograph

MAP	PHOTOGRAPH
Orthogonal projection and uniform scale. Terrain relief without distortion (contour lines). All objects are represented also the no visible An abstract representation Representation geometrically correct Elements appear displaced in its real position and in different shapes, due to the generalization process.	Central perspective projection ; Variable scales ; Relief displacement in the image; Only objects that are visible; Is a real representation; of the earth surface, no legend needed. Representation geometrically not correct Objects appear displaced due to geometric distortions.

2. General diagram for a single photo:

In photogrammetry, it is often possible to obtain scene measurements from a single photo.

That is, we will not be creating a three-dimensional model so that we can measure the dimensions, but rather with a single image that can, but there must necessarily be known points in the image by topographic upload.

Below a discerption of all kinds of computer treatments that we can used on a single photo:

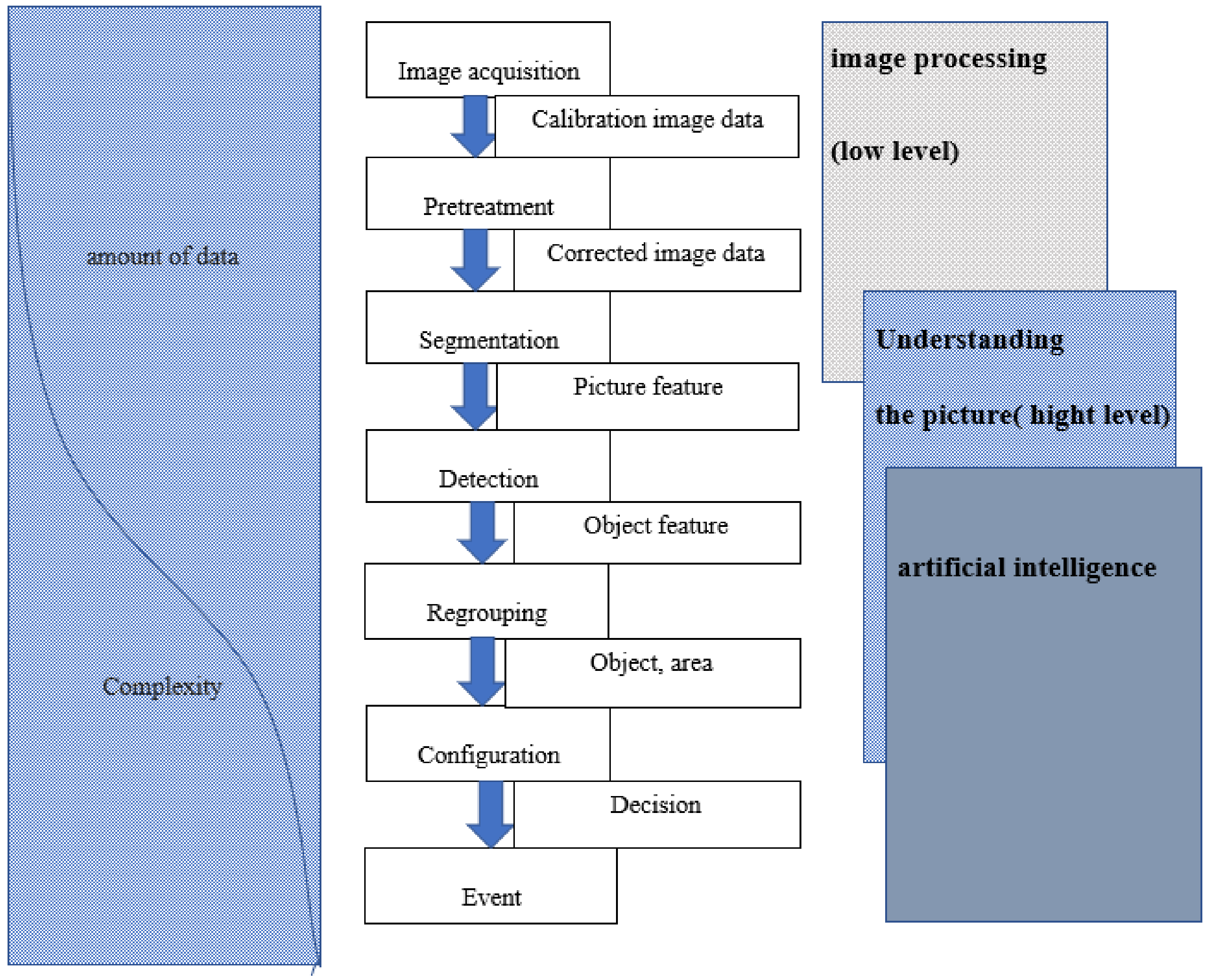


Figure 15 :Image processing sequence.

IV. THE INTERNAL AND EXTERNAL PARAMETERS OF THE CAMERA:

Camera parameters used in a camera model to demonstrate the mathematical dealings between the 3D coordinates of a point token in the scene which the light comes from and the 2D coordinates of a projection onto the image plane. The intrinsic parameters, also known as an internal parameter of the camera, are the parameters intrinsic to the camera itself with the focal length and lens distortion and other parameters. They are also known as external parameters or camera pose, used to describe the transformation between the camera and its external objects.

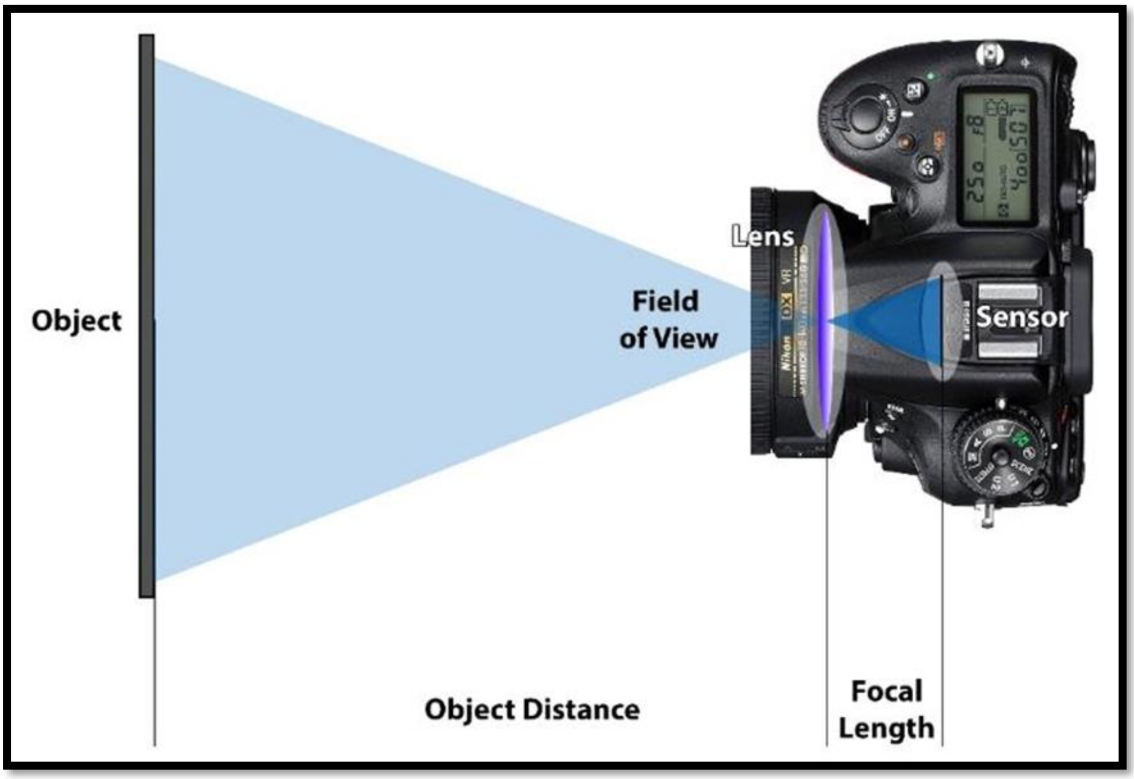


Figure 16: The internal and external parameters of the camera. [28]

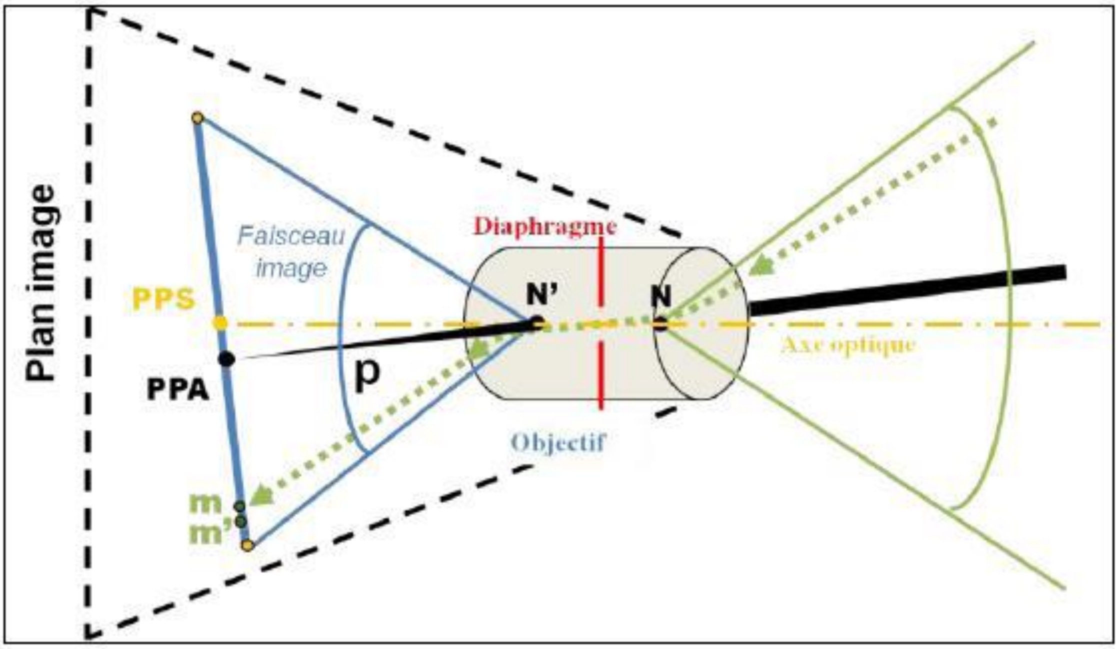


Figure 17:Geometry of the various internal parameters of the camera. [32]

V. CALIBRATION OF THE CAMERA:

Camera calibration is the process of determining certain parameters of a camera in order to fulfill desired tasks with specified performance measures. The reader is referred to entry Calibration for a general discussion on calibration. [33]

In other words, the calibration consists in the extraction and the quantification of the errors of the distortion of the camera used These errors result in the longitudinal and transverse and radial displacement of each pixel of the photo from its true position in relation to the scene photography. [33]

Note that the deformation resulting from the distortion can be visually noticeable on some photographs or not despite its existing in all photographs. As an example, distortions are detectable for linearly structured objects such as building facades compared to natural objects. [33]

To overcome this problem which hinders its only visual aspect but presents a major obstacle for the essential bit of photogrammetry, namely the geometric measurements on the image. We need a whole procedure called calibration before we start taking pictures. [33]

It is therefore a matter of preparing a scene called a canvas which will serve as a geometric reference for the said operation.

Indeed, the canvas is nothing but printed paper containing a point grid (100 point as indicated in the figure below), necessarily equidistant.

Even for the same camera, some photos present deformations, moreover, these anomalies cannot be detected on other photos and this for the simple reason of the distance between camera and scene and the nature of the objects photographed.

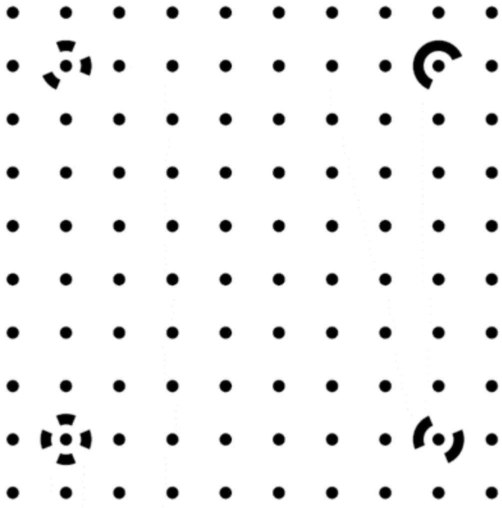


Figure 18: Photo modeler calibration Canva

This canvas also contains marking points with different symbolization. In practice, we have to photograph the canvas from these four sides from each side we will take 03 photos according to the orientations of the camera, namely camera in ordinary position, in 90 ° green on the left side and at the end in 90 ° towards the right side. In total, we will take 12 photos on the canvas.

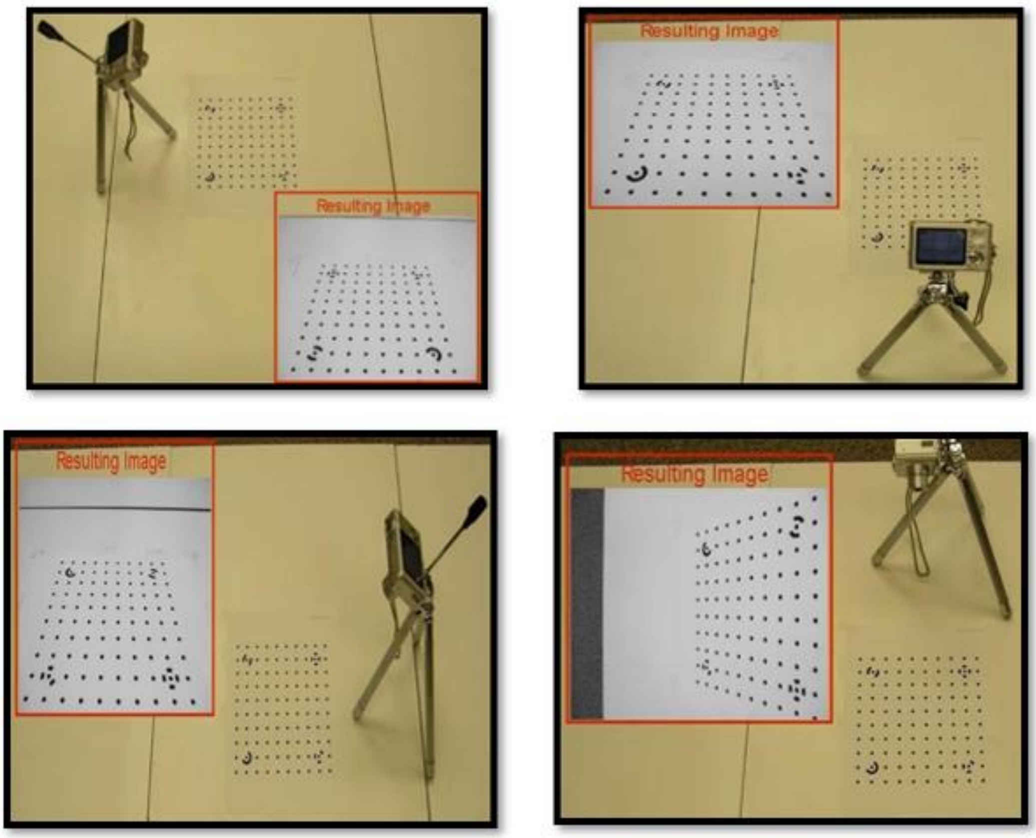


Figure 19: Different angle of capture angle

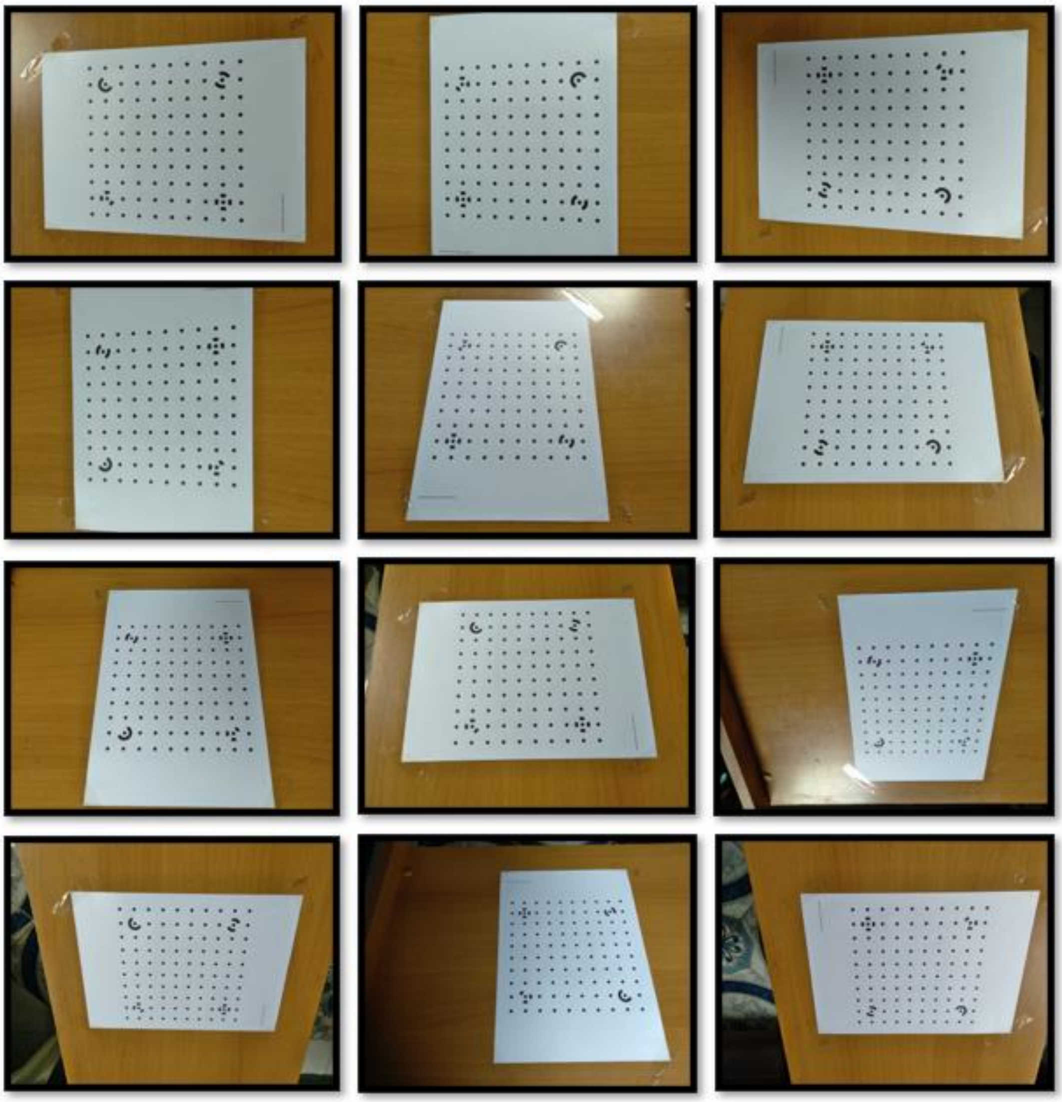


Figure 21 :The 12 photos on the canvas.

The difference in the symbol of the marking points, will help the program to easily detect the camera positions according to the side and according to its orientation.

The software calculates the transverse, longitudinal and radial displacement for each point and then generates a calibration report specifically for the type of camera used.

This file will be used as support of calculation for each operation carried out by the cameras calibrate that we do’t have to calibrate our camera before each photogrammetry operation. The software puts the relation between the photos and the calibration parameters recorded through the metadata of the images inserted because they necessarily contain in their properties the type of cameras used.

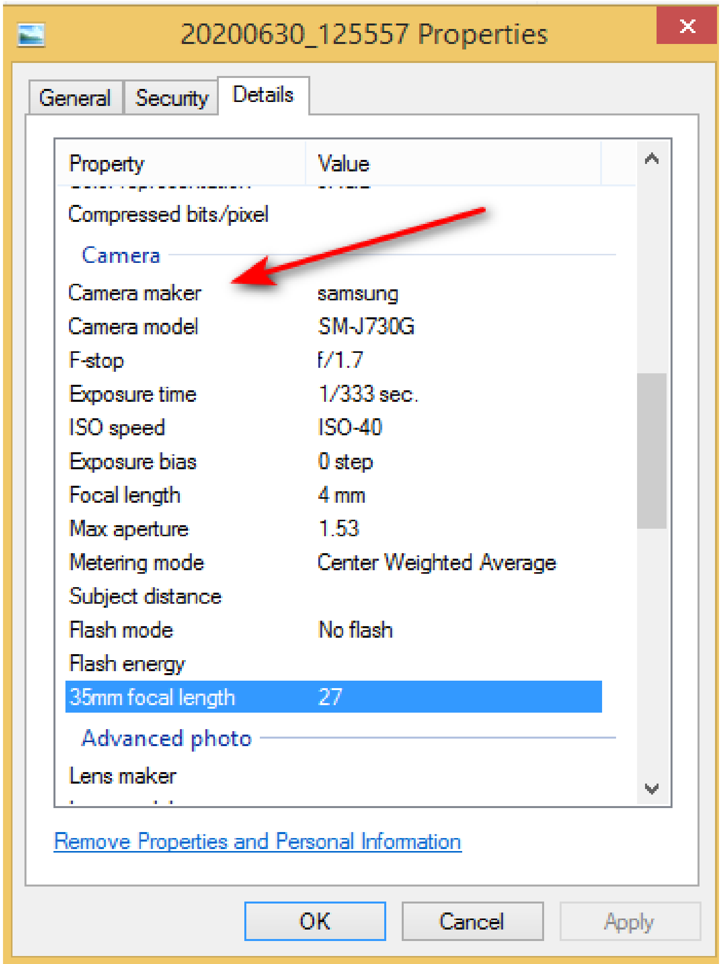


Figure 22:The camera type in the metadata of a photographed image in the photo properties tab.

Some photogrammetric software can detect the calibration parameters by a connection to the servers which there is a database of certain types of cameras already calibrated.

1.1. Code Targets:

Targets with an additional template that encodes an individual point identification number can be used to automate point identification. Codes, like product barcodes, are arranged in lines, rings, or regions around the central target point. Templates can be designed that encode more than several hundred-point identification numbers. Coded targets must meet the following requirements:

- Invariance with respect to position, rotation and size;
- Perspective invariance or affine distortion;

- Robust decoding with error detection (even with partial occlusions);
- Precisely defined and identifiable center;
- Sufficient number of different point identification numbers;
- Detectable pattern in any image;
- Fast processing times for pattern recognition;
- Minimum size of the pattern;
- Low production costs. [34]

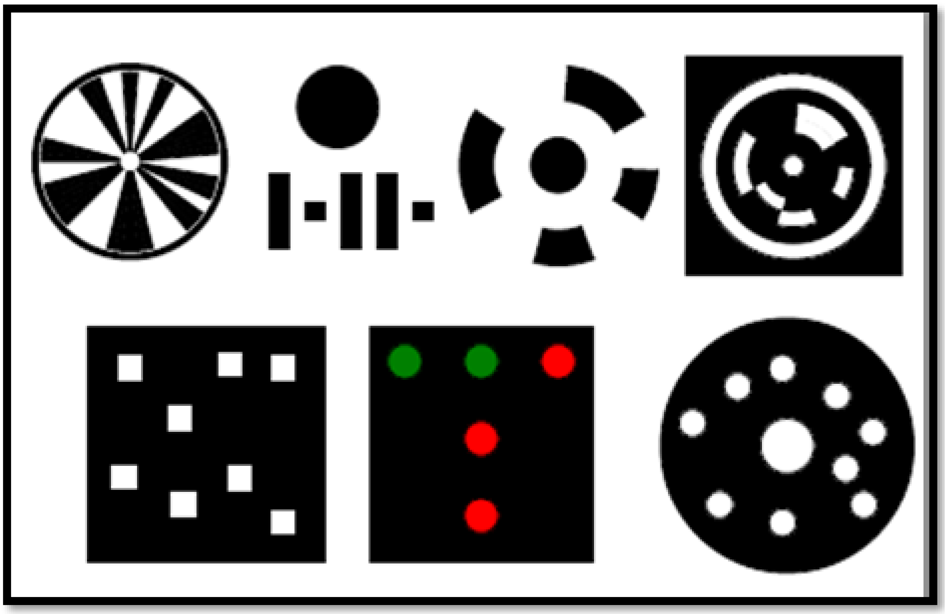


Figure 23:Selection of coded targets Top row: barcode templates, Bottom row: shape and color patterns. [28]

CHAPTER III : METHODOLOGY

I. PHOTOGRAPHY:

1. Photography -The First Part of Photogrammetry:

Taking photographs is, of course, essential for making a photogrammetric measurement. To obtain the high accuracy, reliability and automation the system is capable of, photographs must be of the highest quality. Fortunately, because of the design of the system. [35]

The three main considerations for good photography are:

- ✓ Field of View
- ✓ Focusing
- ✓ Exposure

1.1. Field of View:

The camera’s field of view defines how much it sees and is a function of the focal length of the lens and the size (often called the format) of the digital sensor. For a given lens, a larger format sensor has a larger field of view. [36]

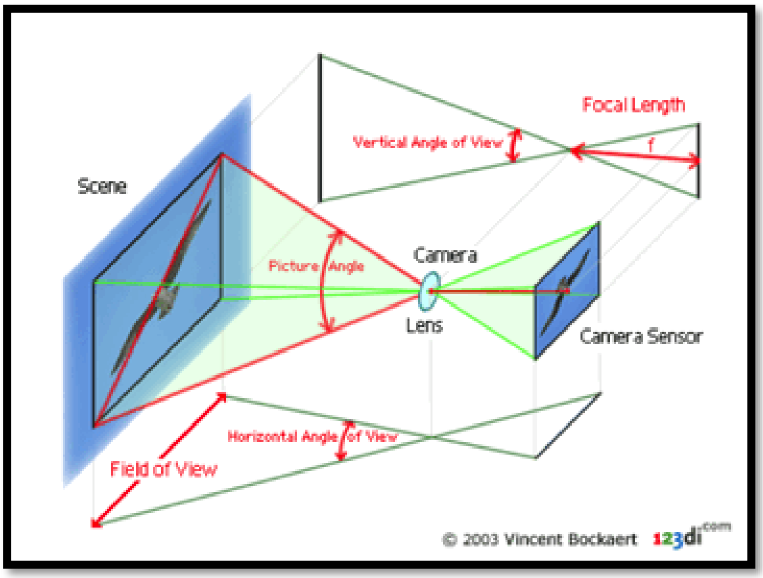


Figure 24:Principe of field of view FOV. [37]

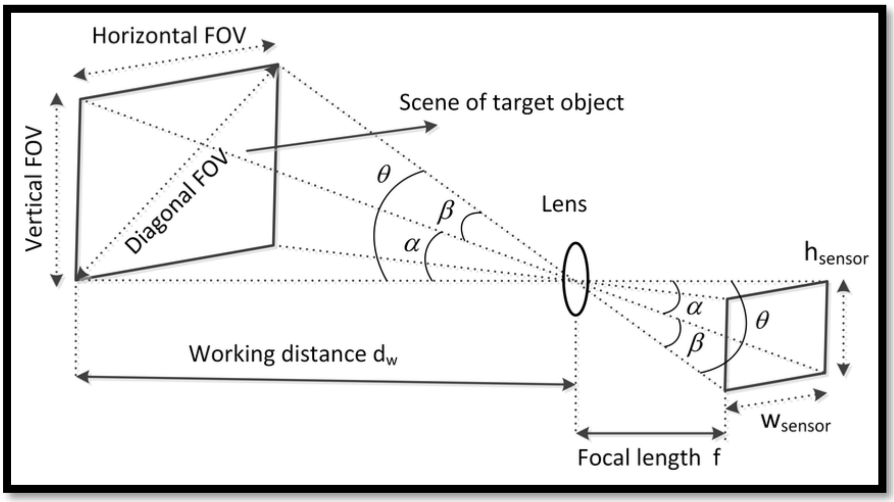


Figure 25 : Angle of FOV. [37]

1.2. Focusing:

The focusing on the lens so the image is sharp.The range of acceptable sharpness is called the depth of focus. it has a function, including: the focal length of the lens, the format size, the distance from the camera to the object, the size of the object, and the f-number of the lens;the depth of focus can be a complex function. [35]

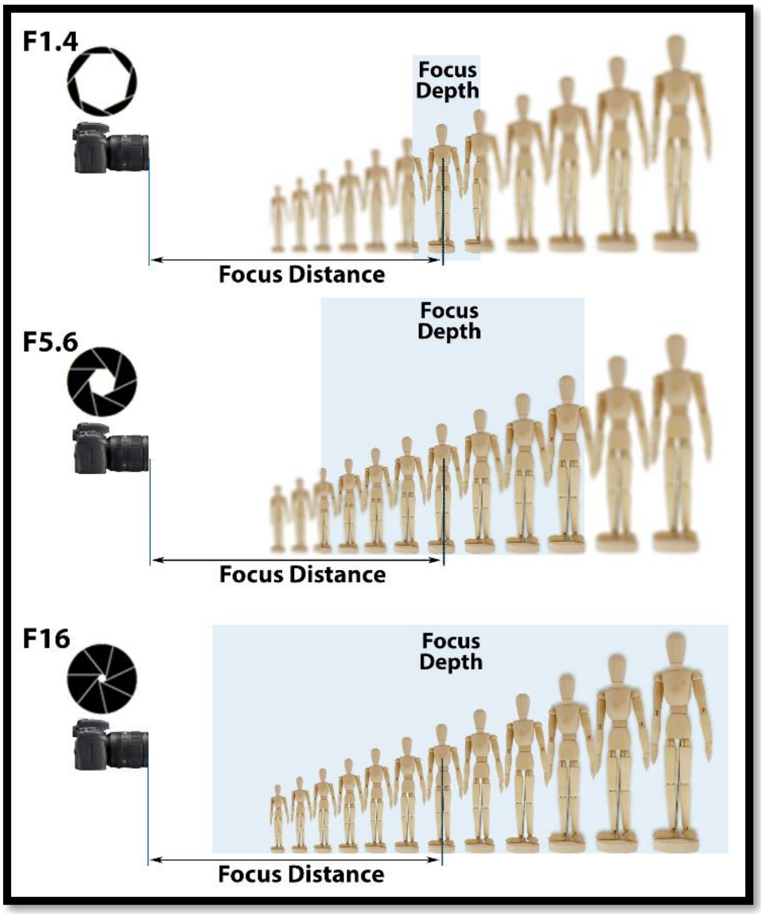


Figure 26:F-number to focus depth relationship. [35]

1.3 Exposure:

Achieving the correct exposure is a lot like collecting rain in a bucket. While the rate of rainfall is uncontrollable, three factors remain under your control: the bucket's width, the duration you leave it in the rain, and the quantity of rain you want to collect. You just need to ensure you don't collect too little ("underexposed"), but that you also don't collect too much ("overexposed"). The key is that there are many different combinations of width, time and quantity that will achieve this. For example, for the same quantity of water, you can get away with less time in the rain if you pick a bucket that's really wide. Alternatively, for the same duration left in the rain, a really narrow bucket can be used as long as you plan on getting by with less water. [38]

In photography, the exposure settings of aperture, shutter speed and ISO speed are analogous to the width, time and quantity discussed above. Furthermore, just as the rate of rainfall was beyond your control above, so too is natural light for a photographer. [38]

2. Image Exposure:

For photogrammetry purposes, it is desirable to set the targets bright and the background dim. When retro-reflective targeting is used, the target and background exposures are almost completely independent of each other.

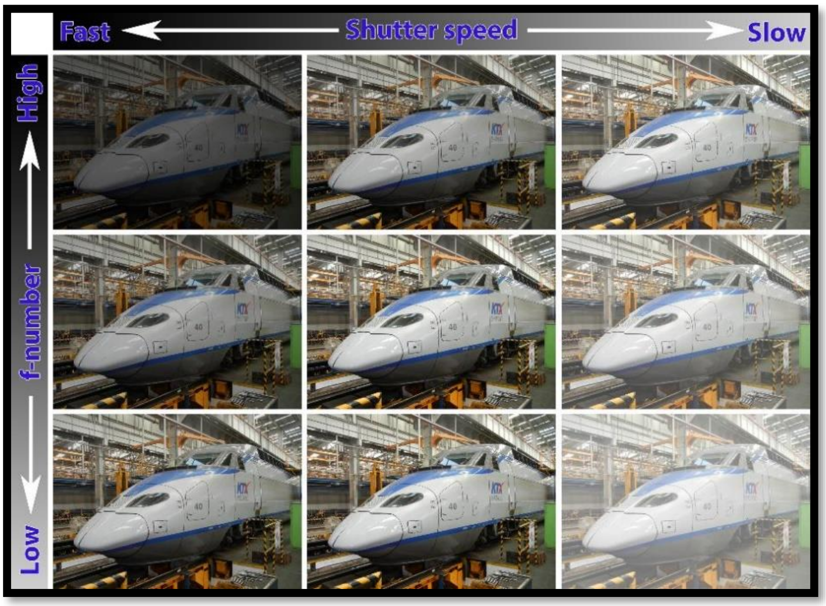


Figure 27: Relationship between shutter speed and F-number. [35]

3. Background Exposure:

The shutter time is used to control the background exposure.

4. Target Exposure:

The flash power setting for the target exposure depends on the distance from the camera to the targets, and the target size.

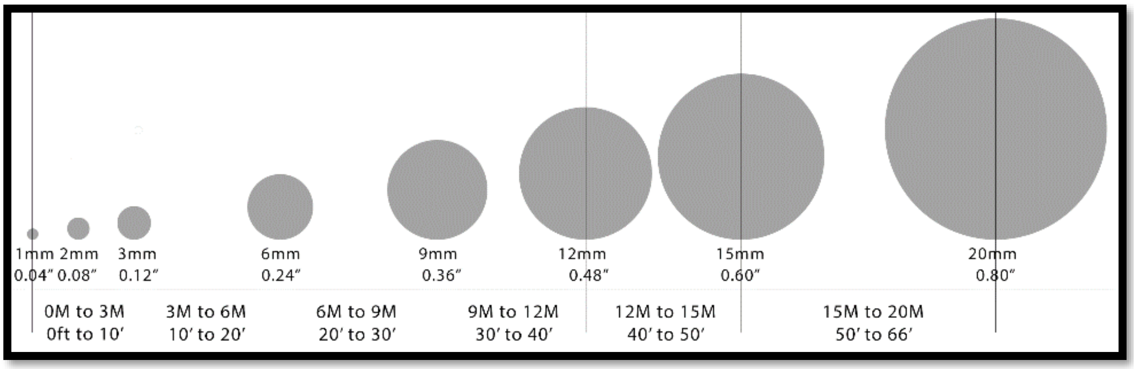


Figure 28 : Recommended target size versus distance. [35]

II. METROLOGY:

1. Metrology – The Second Part of Photogrammetry:

Photography in his basic sense is a process that converts the real 3-D into flat 2-D photos. The camera is the equipment that makes this transformation. Unfortunately, we can't map the real 3-D world from two dimensions completely that why some information is lost specially primarily the depth. in photogrammetry we need more than two pictures to reconstruct the 3-D world and another extra information to improve the process.

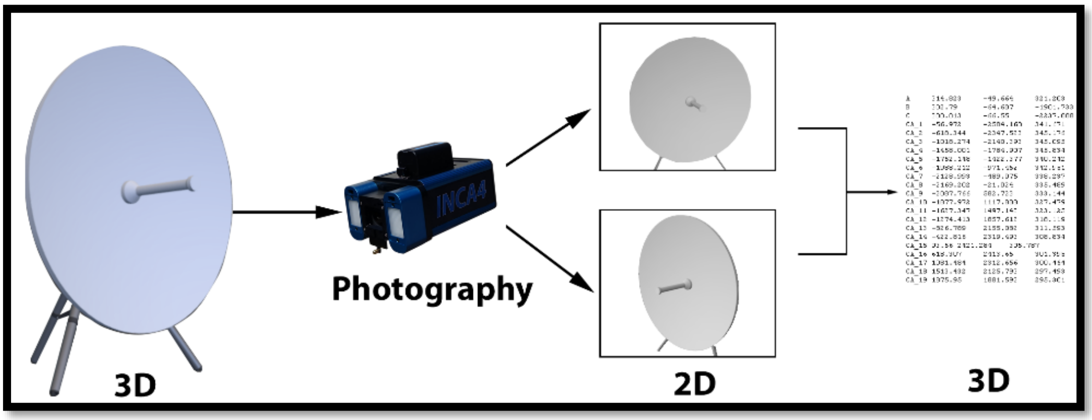


Figure 29 : 3D to 2D images to 3D coordinates. [35]

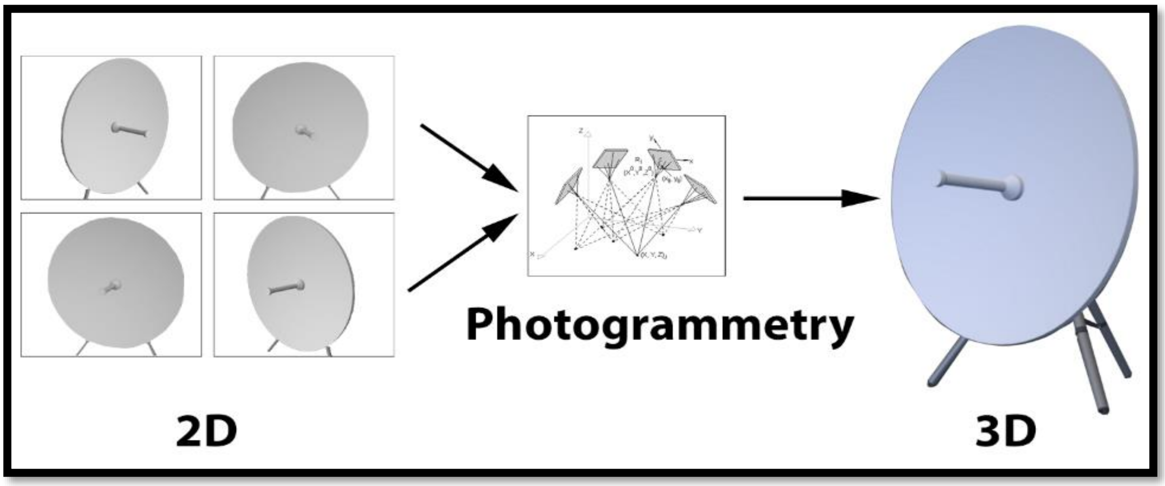


Figure 30:Photogrammetric process to convert 2D to digital 3D. [35]

2. Triangulation:

Triangulation is the principle used by both photogrammetry and theodolites to make 3-D dimension and lines that will be intersecting in space, the precise location of the point can be determined and photogrammetry can measure multiple points at a time with virtually no limit on the number of simultaneously triangulated points.

But in the case of theodolites, two angles are measured to generate a line from each theodolite. However, in photogrammetry, it is the two-dimensional (x, y) location of the target on the image that is measured to produce this line.

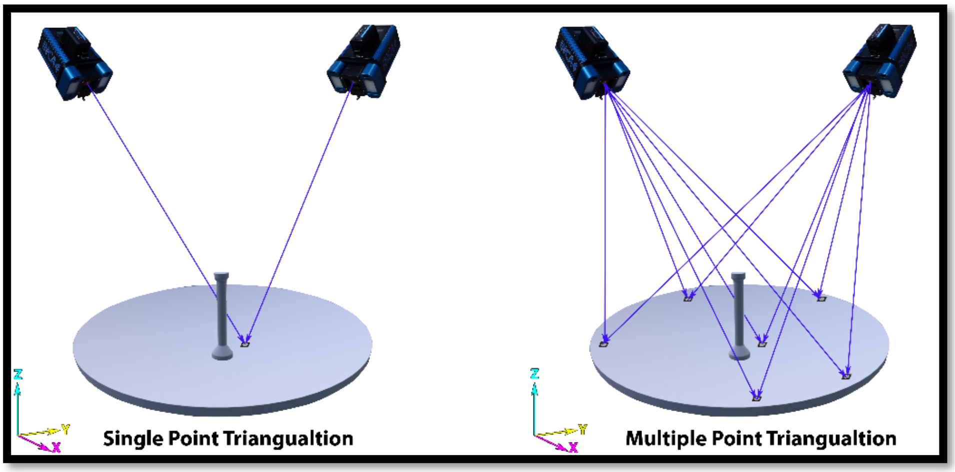


Figure 31 : Single and multiple point triangulation. [35]

3. Resection:

This procedure used to determine the final position and aiming (called the orientation) of the camera when a picture is taken. usually, all the points that are seen and known in XYZ in the image are used to determine of the orientation.

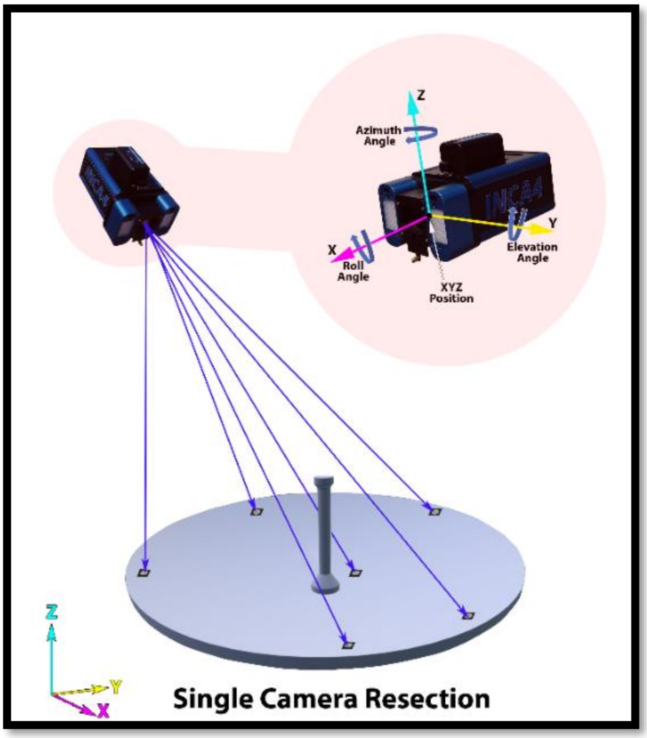


Figure 32 : Single camera resection. [35]

4. Self-Calibration:

The ability to calibrate and measuring of the camera is called Self-calibration and it means the camera will be calibrated at the time of measurement, in different environment conditions exist at the time of action. This is more interesting from an old laboratory calibration possibly outdated in different conditions than existed at the time of measurement.

Figure 33 : Camera roll. [35]

5. Bundle Adjustment:

Is the program that processes the photographic measurements get the final coordinates XYZ of the measured points.so it must Triangulate the target points, truncate the pictures and Self-calibrate the camera. The Bundle Adjustment program is called STAR, which stands for Self-Calibration, Triangulation and Resection.

1. XYZ coordinates (and accuracy estimates) for each point;

2. The XYZ coordinates and 3 aiming angles (and accuracy estimates) for each picture;

3. The camera calibration parameters (and their accuracy estimates).

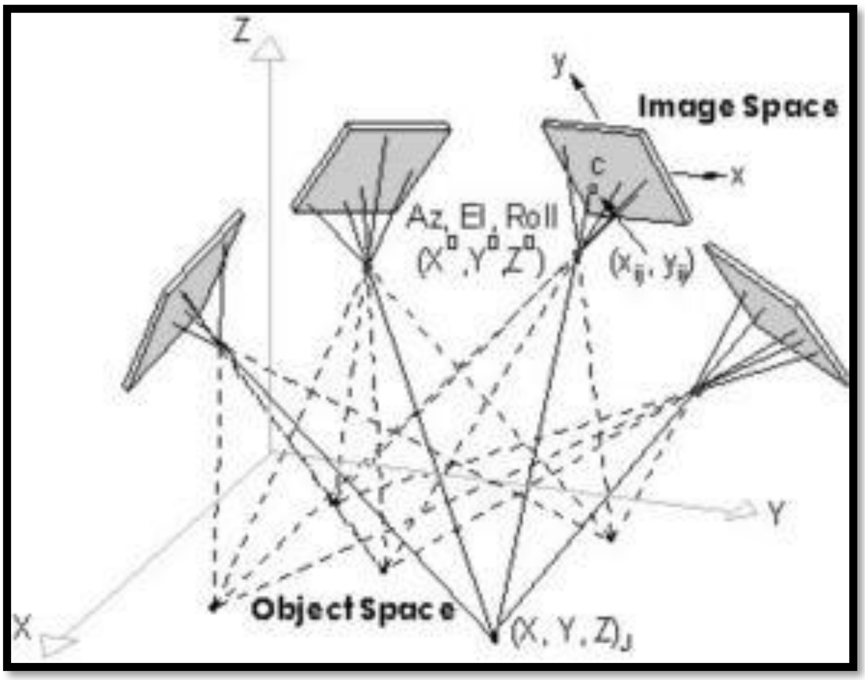


Figure 34:angle of The Bundle Adjustment. [35]

6. Measuring Accuracy:

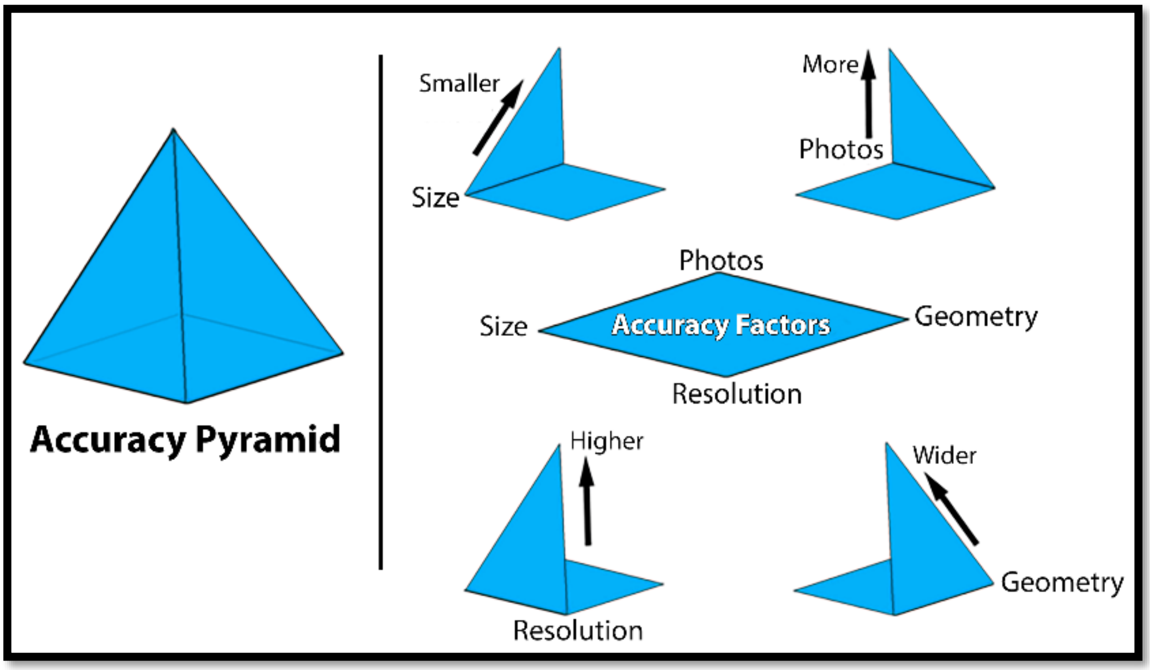


Figure 35 :Accuracy pyramidefactor. [35]

III. SCALING PHOTOGRAMMETRY:

For an imaging scale, it should be at least one known distance. If we know some of the coordinates before measuring the target points, help in calculating the distances between these points and using them for the tape measure. Then we can use equipment with targets on them and get this along with the object. The distance between the targets on the tape is known and can be used.

1. Multiple Scale Distances:

Multiple Scale Distances combines the individual scale measurements to provide higher scale accuracy. More importantly, this allows you to find scale errors. when a single scale distance is used and it is in error, the entire measurement will be incorrectly scaled. Then if we have multiple scale distances, the scale errors can be clearer and more detected that will help us to remove it. With three known scale distances, we can usually detect if one of them is in error and remove it.

2. Long Scale Distances

The long scale distance(s): should be practical to coordinate with the size of the object.

IV. MEASURING:

Regardless of the type of measurement, we always follow the following steps.

1. Measurement planning;

2. Target the object;

3. Take pictures;

4. Image measurement;

5. Image processing (to obtain 3-dimensional coordinates);

6. Analyze the results (manipulate the results to help verify and visualize the results).

However, each measurement project is different according to the needs.

1. Planning the Measurement:

For a successful measurement, we must plane to provide the complex.

2. Defining a Coordinate System:

All coordinate measurement systems must use some working coordinate system.

The plan must include a way to define the user coordinate system you desire.

Often, the user coordinate system is defined by a subset of the measured points that have coordinates in the user's desired coordinate system. These points may consist of precisely made tooling targets that are located in bushed holes, or they may be defined by features on the measured object (such as part edges, or hole locations or intersections of lines, planes, etc.) that are targeted in some way. In any case, it is important that the points representing the user-defined coordinate system be targeted precisely or else the accuracy of the transformation will be degraded.

Coordinate systems are also called axis systems since the coordinate system is often defined by aligning certain points to the coordinate axes. In this document, coordinate system and axis system are used interchangeably and mean the same thing.

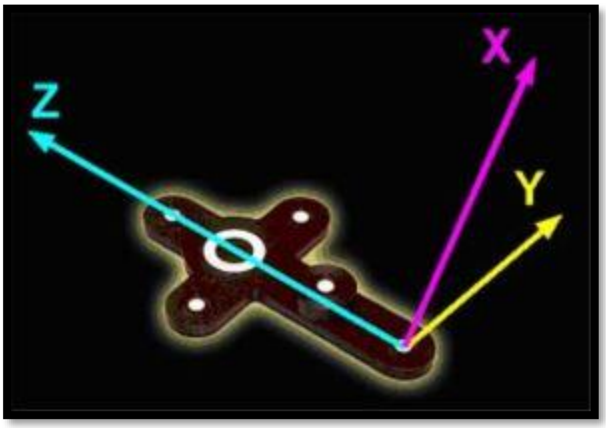


Figure 36 : corresponding coordinat system. [35]

V. MEASUREMENTS:

1. Types of Measurements:

Photogrammetry is a versatile, powerful, and flexible measuring technology. Measurements have been done on land, sea (and undersea), and air, and even in outer space on objects smaller than a football to larger than a football field.

Photogrammetry is widely used in the aerospace, antenna, shipbuilding, construction, and automotive industries for a wide variety of measurement tasks. Although every photogrammetric project is somewhat different, we have separated them into broad categories to help describe general approaches for performing a successful measurement.

Measurements can be classified as initial or repeat, and as completely overlapping or partially overlapping. The two categories are not mutually exclusive; initial measurements can be completely overlapping or partially overlapping, and so can repeat measurements. In general, a completely overlapping, repeat measurement is the easiest type of measurement while an initial, partially overlapping measurement is the most difficult.

FIGURE 37: Typical objects measured via photogrammetry. [35]

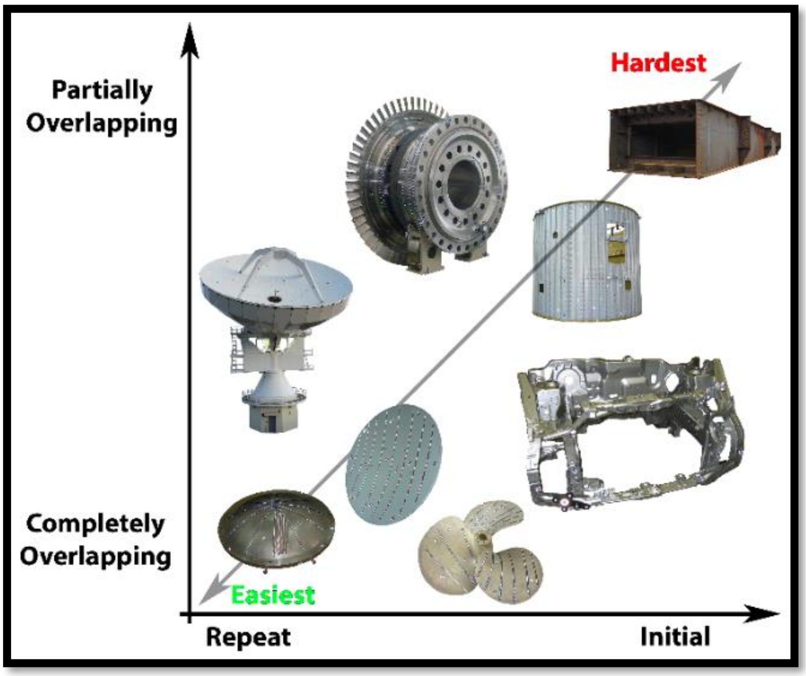


Figure 38 : Pictorial graph indicating relative difficulty of different measurements. [35]

A repeat measurement for coordinate point is one in which approach are available for all (or nearly all) the coordinates are available from an earlier measurement of the object (hence the name repeats measurement), but they can also be from a set of design coordinates. All that matters is that they are accurate enough to allow the software to correctly measure all the targets on each photograph.

2. Completely or Partially Overlapping Measurements:

A completely overlapping measurement is one in which the entire object is seen in every photograph, while in a partially overlapping measurement, the object must be photographed in sections. Partially overlapping measurements must have sufficient common coverage to hold (or "tie") the entire measurement together as a unified whole.

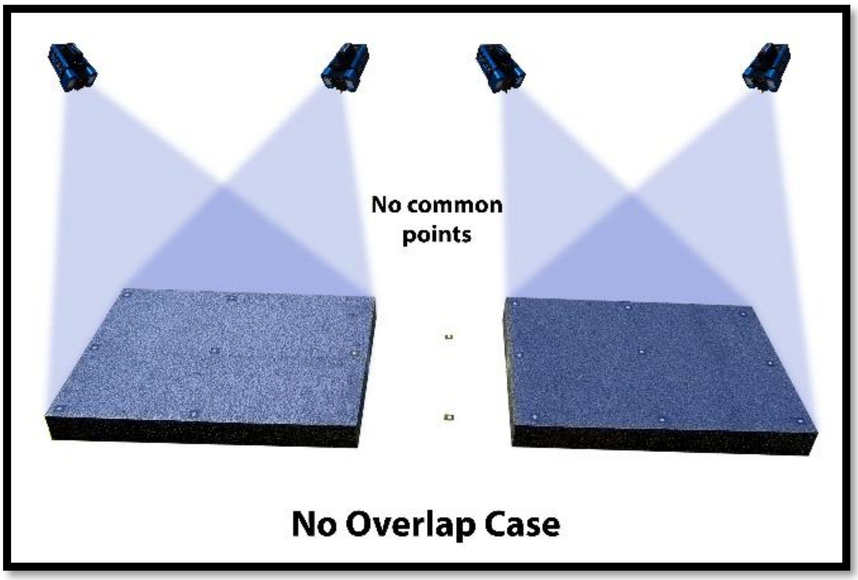


Figure 39 :No overlap of object measurements. [35]

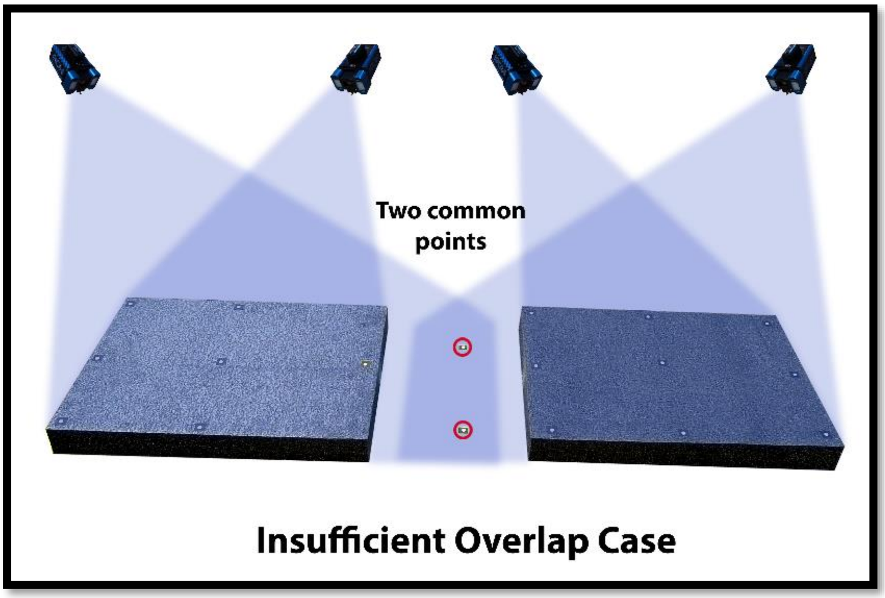


Figure 40 :Insufficient overlap measurement. [35]

If we now add a third point in common between the two measurements that is away from the line (so the three points form a triangle), the "hinge" is now locked in place and the relationship between the two panels is established.

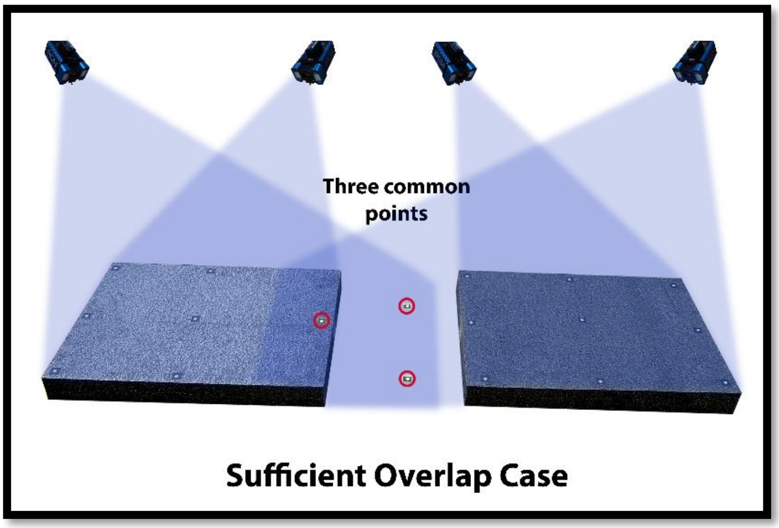


Figure 41 :Sufficient overlap measurement. [35]

Of course, by adding more points and more overlap the tie between the two panels is more strongly established. The strongest tie between the two panels is established when all pictures see all of both panels; and we find ourselves back to the completely overlapping type of measurement.

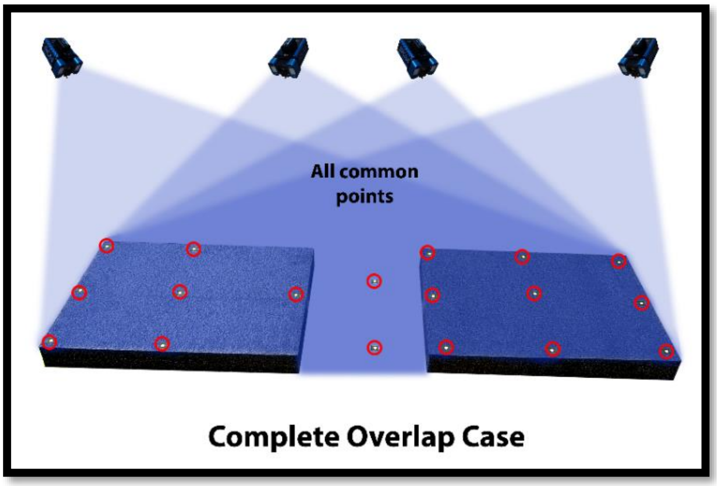


Figure 42 : Complete over lapping measurement. [35]

VI. PLANNING FOR MEASUREMENTS:

1. Planning for Different Types of Measurements:

If the measurement of a project is a primary or repeat usually has no effect on his design but in stat define the procedure usually pursue to implement the design in the most efficient manner.

Firstly, discuss design for completely overlapping measurements since these are the easiest type of measurements, next we discuss the design for partially overlapping measurements that are more complicated. finally, we discuss the general procedures for the different types of measurements.

2. Design for Completely Overlapping Measurement:

Design for Completely Overlapping Measurements in real state to get a highest accuracy, the photographs should be taken from many different locations from other angle that produce good intersection of the points on the object.

So, the main considerations for design of overlapping measurements then are:

- seeing all targets from many locations (for good accuracy and reliability);
- keep camera intersection angles between 60° and 120° (for good accuracy);
- keep angles to retro-reflective targets less than 60° (for good, bright target images).

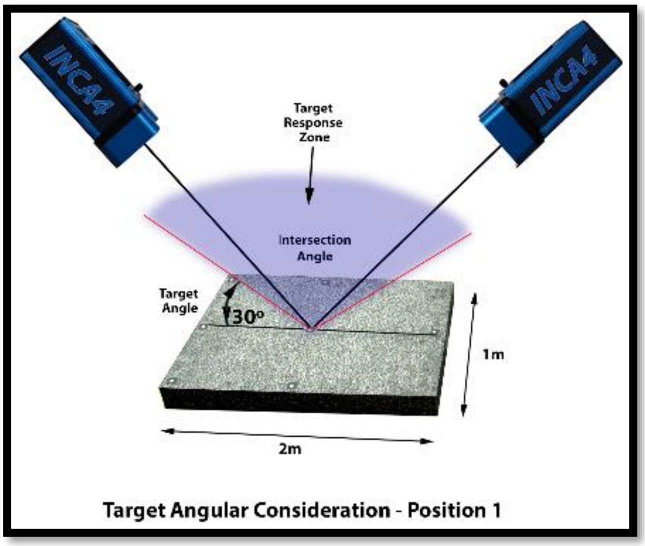


Figure 43 :Measurement angle consideration. [35]

When the cameras move further the intersection angles between the two cameras gets more larger which is good since it helps improve accuracies, but also the angle to the retro-reflective targets also gets larger which is eventually bad since the targets will ultimately become too dim to be measured.

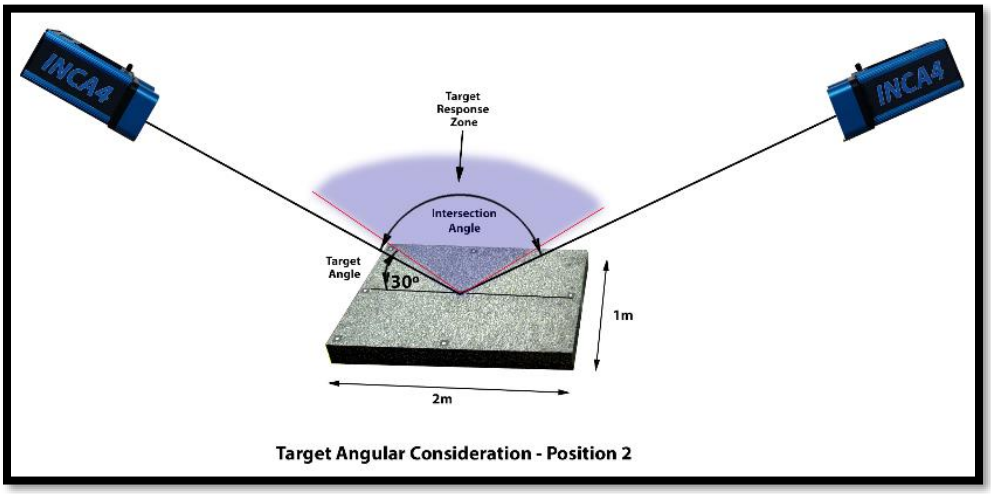


Figure 44 :Target response zone and effect on measurement. [35]

To get a good quality of intersection angles and quality of target image is to locate the camera in 45° angle with the center of the object. This also keeps the angle to the retro-reflective targets that are furthest away from the camera less than the limit of 60° and the angle of 45° to the center of the object is the camera location so it’s easy to figure out; by calculate the distance out from the center of the object is equal to the distance back from the object.by the way the shape of the object also influences the camera locations.

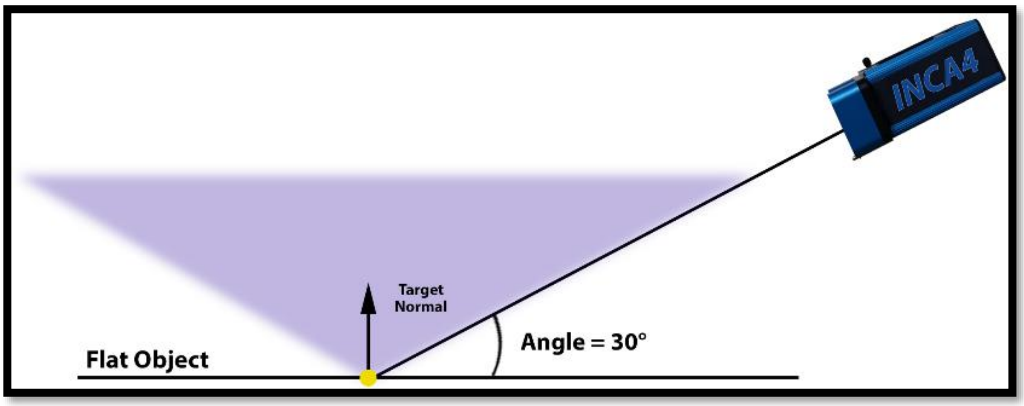


Figure 45 : Target normal versus object topography – flat object. [35]

Contrariwise, if the object were convex, the camera intersection angles would have to be smaller so the retro-reflective targets at the edges could be imaged.

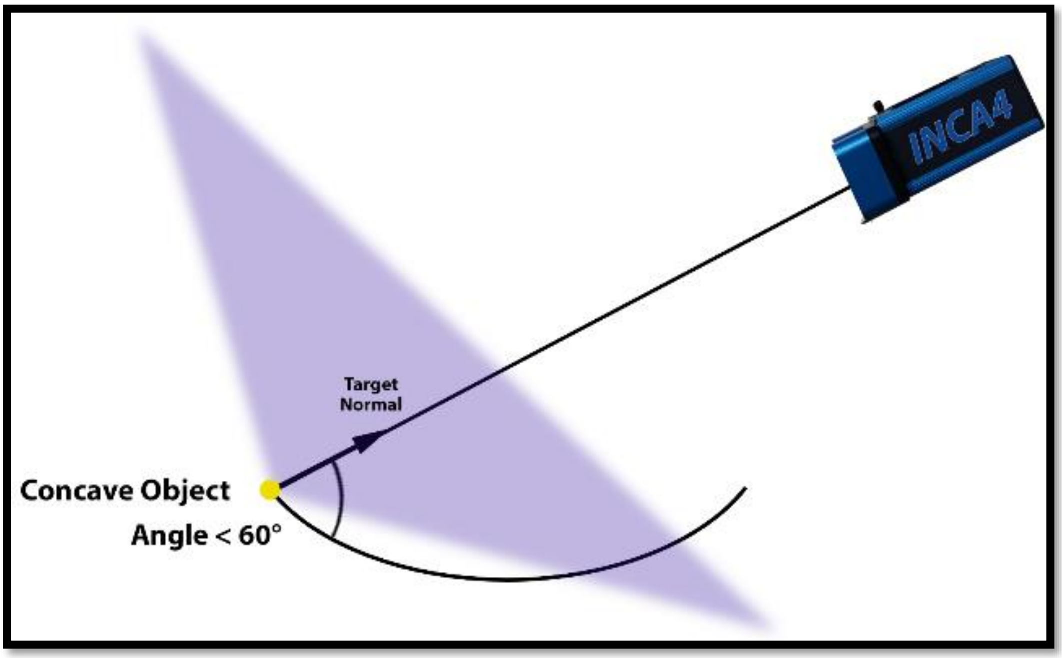


Figure 46 : Target normal versus Object topographie – concave Object. [35]

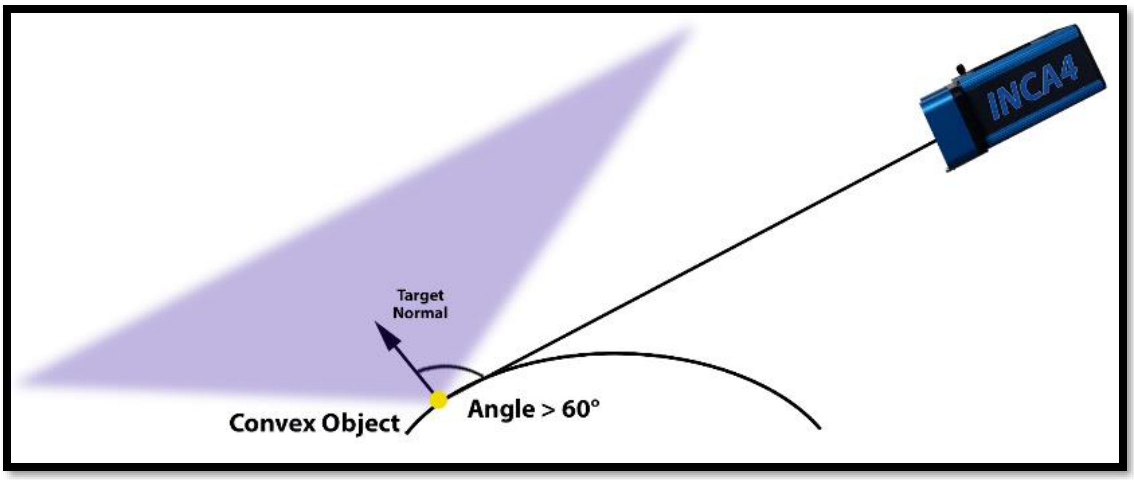


Figure 47 :Target normal versus object topography – convex object.

Try to take extra pictures from other locations to the object that see the blocked targets. However, it can often be difficult to get good geometry if the blockage is severe.

3. Design for Partially Overlapping Measurements:

Overlapping measurements, we must still consider everything required in the planning for completely overlapping measurements. and we must design the measurement so there is enough overlap to tie the whole measurement together strongly enough to preserve the measurement accuracy.

Partially overlapping measurements started out with a "divide and conquer" strategy for the measurement. First, divide the object into several logical areas and side (left, right, front, back, ...ect). Then, add extra photographs (or targets) so that the separate areas.!

4. Design for "Left-Right" Measurements:

Often, an object that could be measured with complete overlap must be measured with partial overlap in order that there is not enough room around the object for the entire object to be seen in every photograph.

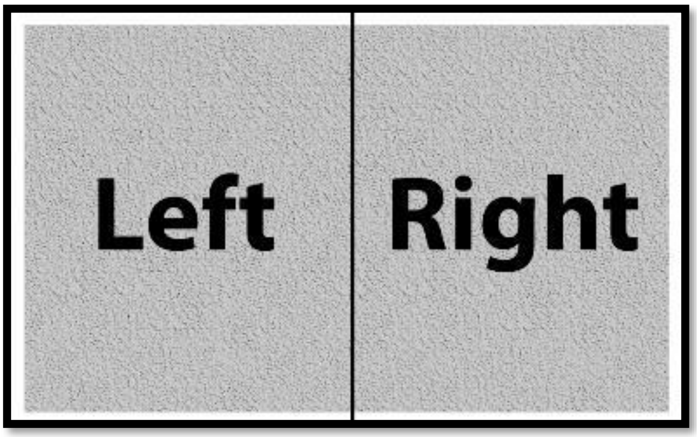


Figure 48 : Dividing the space. [35]

Seeing each half in four photographs from four different locations. can help us but note that there is no combined coverage between the two halves, of the measurement is not connected.

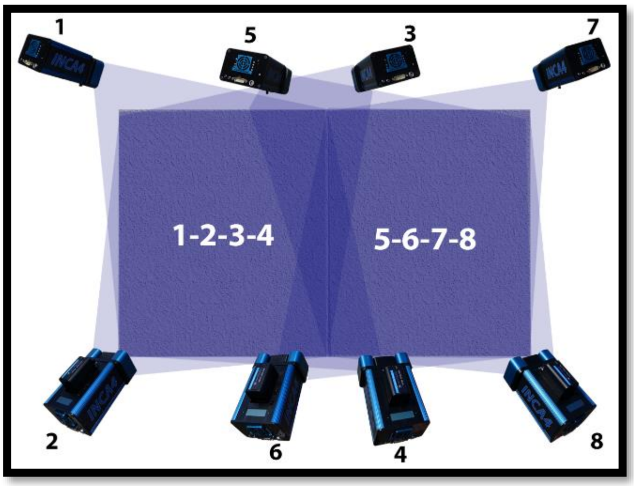


Figure 49 : Insufficient overlap measurement. [35]

There are a couple of different ways to connect the halves together. Firstly; we can take more photographs in the middle that are aimed right at the center of the wall. like we can take two pictures in the center of the wall; one at the top, and one at the bottom. These photographs see part of the left and right halves and serve to tie everything together.

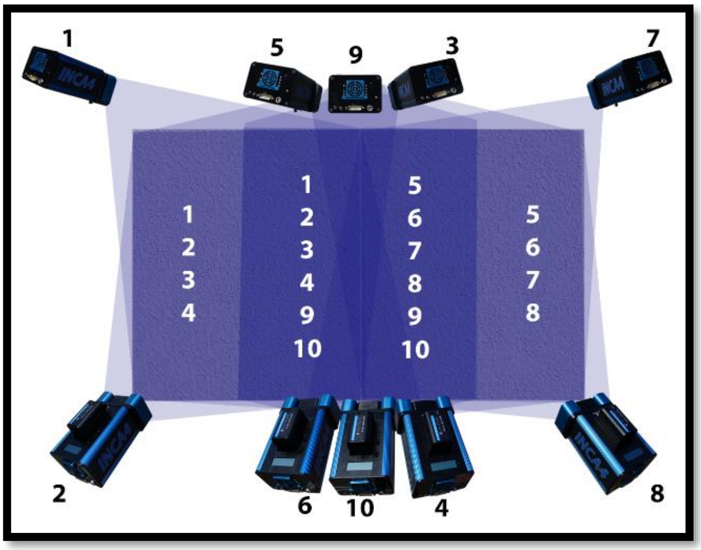


Figure 50 : Adding camera location to improve tie. [35]

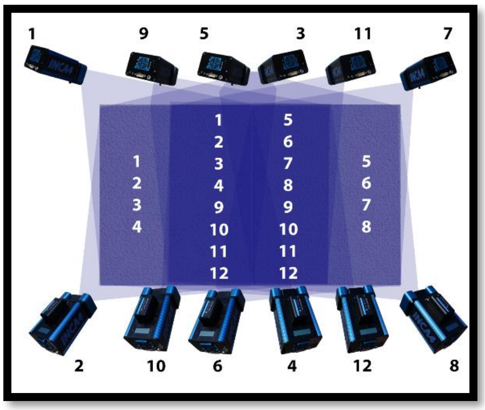


Figure 52:New three section network. [35]

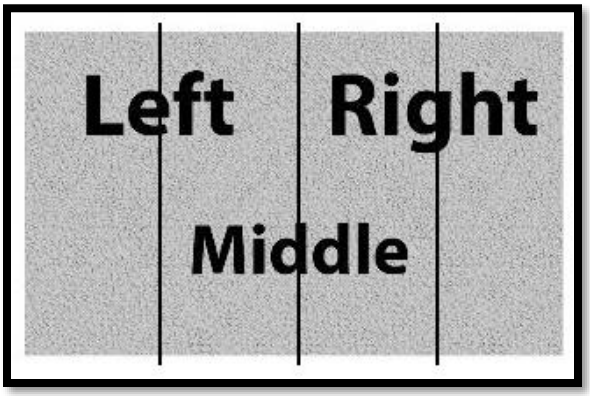


Figure 51 : Division into three parts. [35]

Although this approach is a little harder than the previous one because you must move the camera to these new positions, this approach is somewhat more accurate due to the greater geometric diversity.

5. Design for "Front-Back" Measurements:

We must connect between the front and back with linking points and Mach the two sides .then We must attach targets somewhere that are seen by both the front and back photographs.Twelve well-distributed targets are all that is needed to provide a strong tie between the front and back.

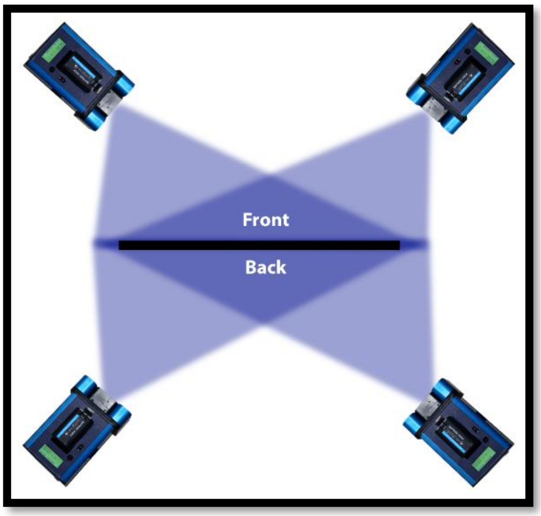


Figure 53 : Front to back measurement. [35]

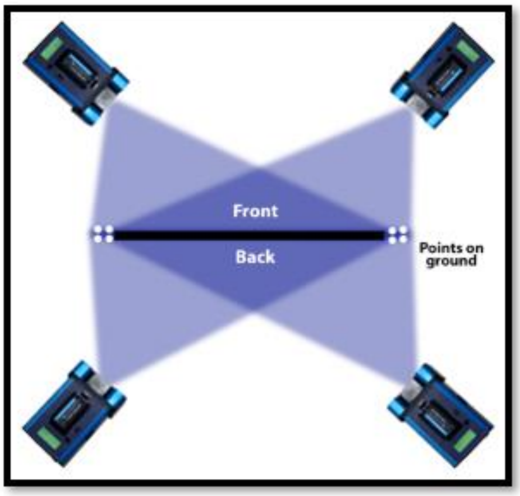


Figure 54 : Front to back connection via floor points. [35]

6. Design for "Box" Measurements:

In a situation that requires partially overlapping measurement occurs when we must measure an object that has multiple sides and front. Usually, we cant seeing all the side of an object frome only one angle we must change our locations and angle for good measurement. A example of this is having to measure all four sides (and sometimes the top and/or bottom) of a box shaped structure. [34]

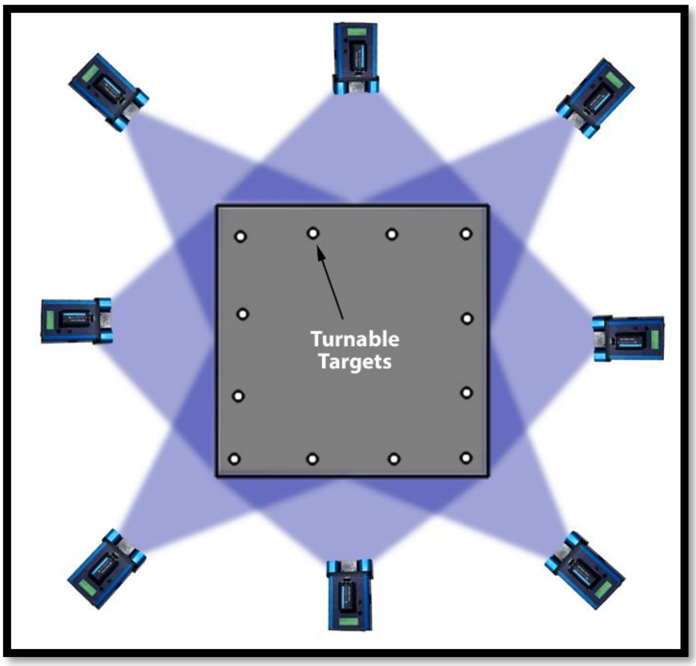


Figure 55 : Box measurement using turntable targets. [35]

And we can have more points mashing by increase the density of codes near the corner and to have codes at 45° to the corner rather than planar (0° and 90°) to the face. The standoff angle of 45° can< increase the visibility of the target moving into and out of the corner.

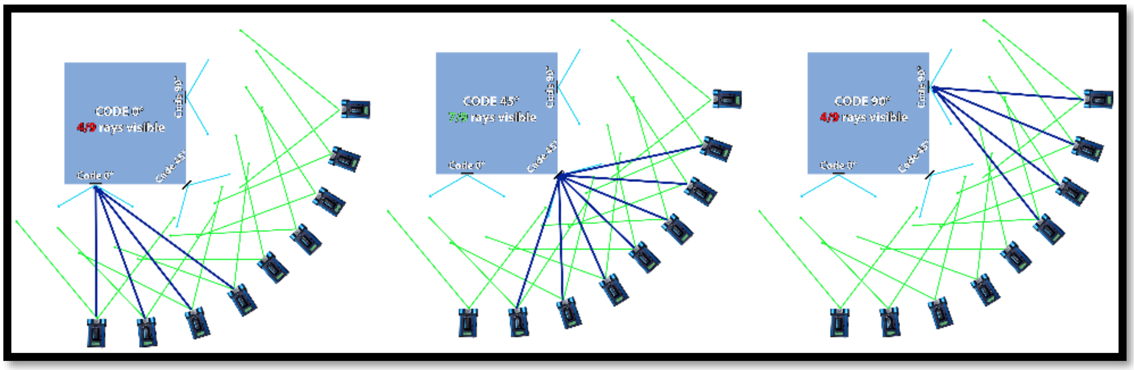


Figure 56 : Visibility with 45°standoff versus 0° and 90°. [35]

CHAPTER IV : APPLICATION

I. INTRODUCTION :

In this chapter we will describe the process for the photogrammetric reconstruction and the proximity of the volumes of the objects. We will also cite our first tests to fully discuss the margin of error committed to highlight the importance of some technical aspects during shooting and the steps followed in the reconstruction.

II. TOOLS USED:

1. Software used:

We opted for the "Photo modeler" software version 2017; it is a commercial software specialized in the processing of photos for photogrammetric use it has a long history as a leading photogrammetric tool. Photo Modeler introduced the concept of a desktop close-range photogrammetry product to the world in 1993 and has been a leader in technology since. Many consider Photo Modeler to be the ‘father’ of modern desktop terrestrial photogrammetry. [39]

The software interface presents a range of different treatments to choose from its start; namely the development of target points, camera calibration, manual modeling, etc. Furthermore, the software does not provide us with a global assistant for a new user, despite the existence of assistants in each chosen operation, we consider that the basic concepts of photogrammetry are necessary and specific training on the software is compulsory for the proper handling of this type of professional software. [39]

2. Device used:

phone mobile : Samsung J7pro; Samsung J7Max; Samsung 6 plus .

Camera: CANON 1200D

Computer: Lenovo inside core i5 ; Asus

OUR FIRST A EXPERIENCE

1. Our first reconstruction:

Figure 57: A reel photo of the object

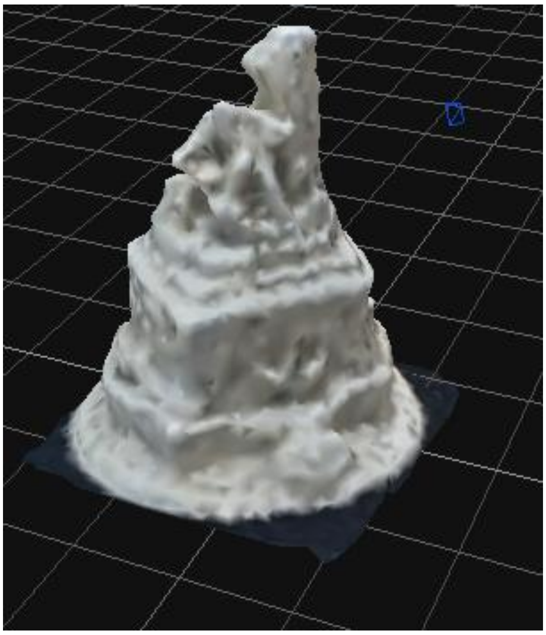


Figure 58: First 3D reconstitution

2. First calculation of the volume of by terrestrial photogrammetry:

First; we focus on the volume result; we take a 1000 cm3 of sugar measured and we shooting after choosing the right methodology of work and the result was 1128.77cm3.

Figure 59: A reel photo of the first reconstitution volume.

IV. METHODOLOGY:

Our work steps divided into three essential following phases:

Firstly, Pretreatment then acquisition; lastly the treatment:

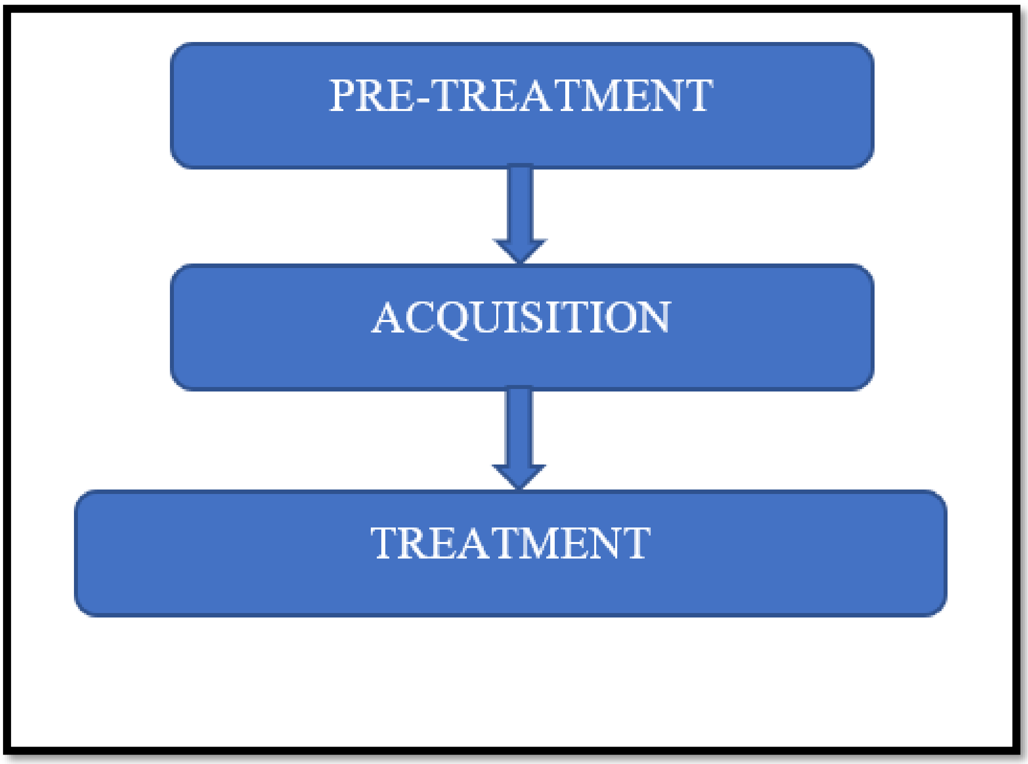


Figure 60: The phases of photogrammetry.

1. Pretreatment:

This is the phase which must Precedes acquisition operation, it's about the steps of calibration of the camera we used (see chapter 3); We can mention it in 6 steps:

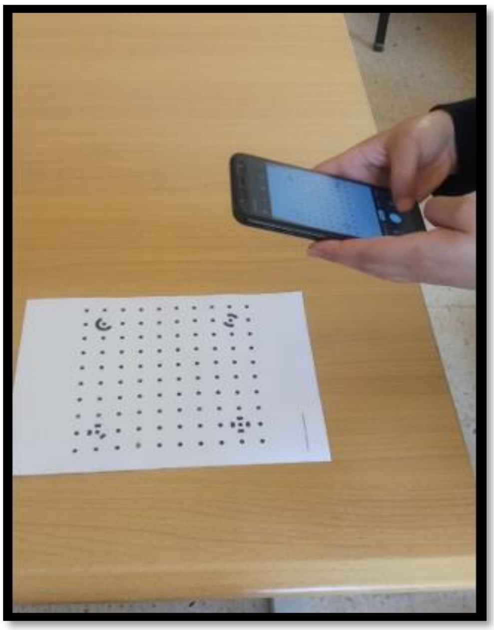


Figure 61: Shooting of the CANVA.

The result of this phases and the calibration reports for our devices uses (j7 pro; j7 max; j6 pro; canon 1200D) are essential for the next phases:

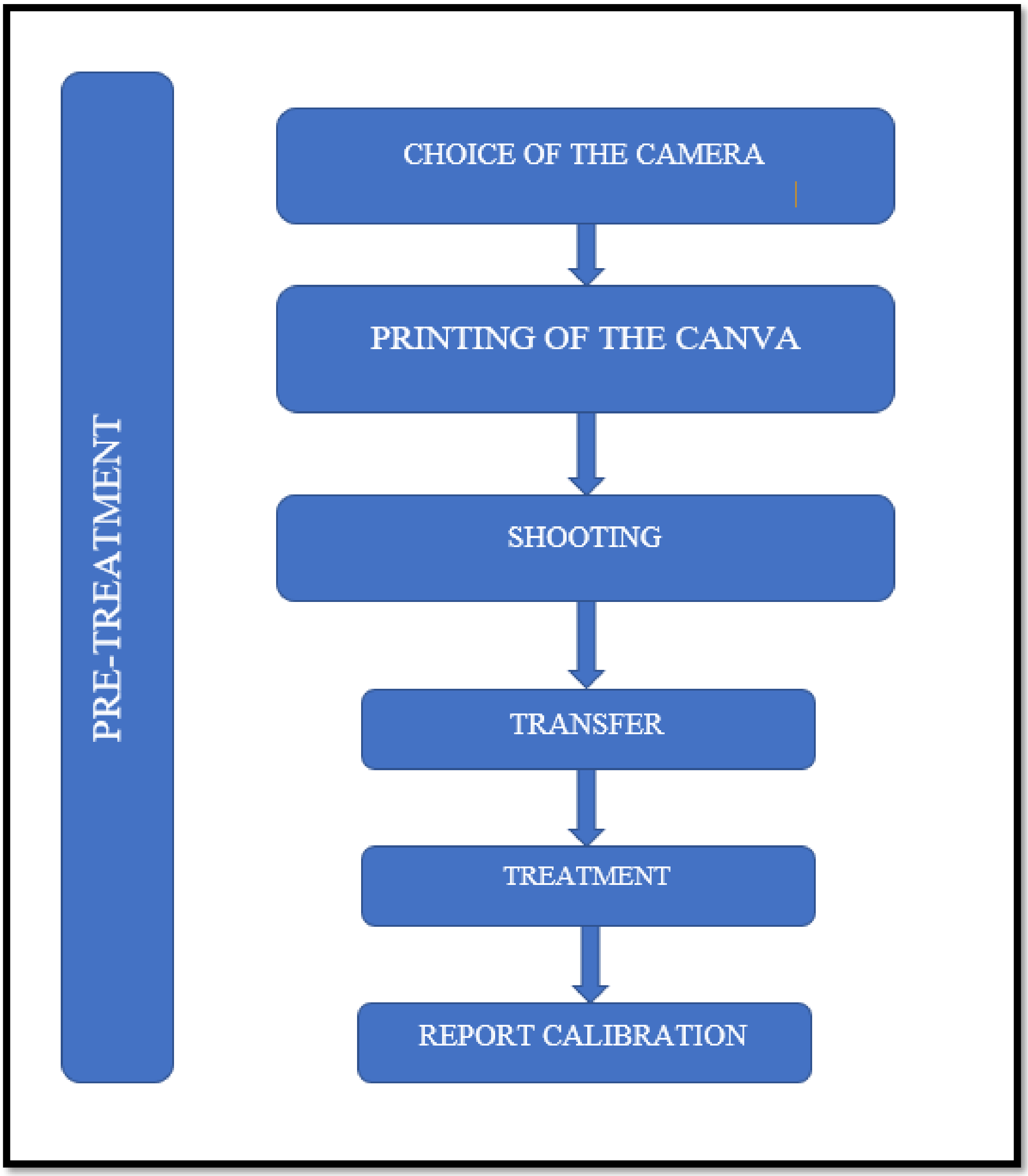


Figure 62:Pretreatment tasks.

2. Acquisition:

The acquisition part is the field data, in the beginning of this phases we chosen 4 types of different materials and colors (sugar; send; gravel; cylinder of concrete).

Before we start this phase, we measure the real volume of our materials that we used and mention it then we put them in flat area:

Figure 64: Measuring Equipment.

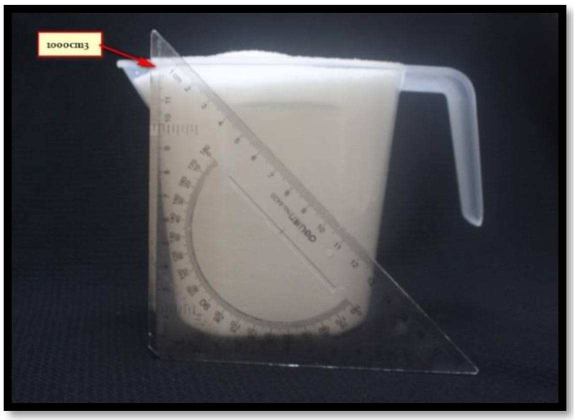


Figure 63 :Knowing volume of sugar.

Figure 66: 2000cm3 volume of cylinder.

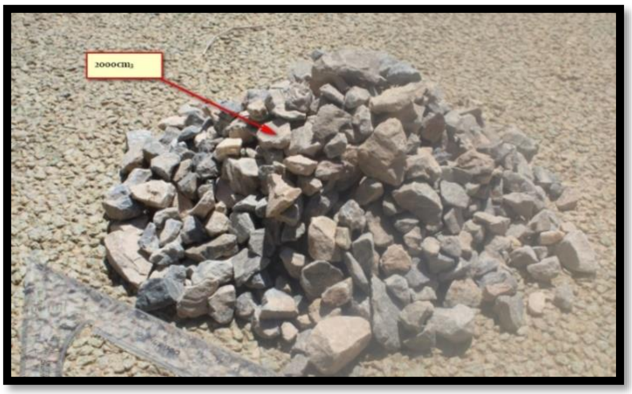


Figure 65: The same volume gravel in flat area.

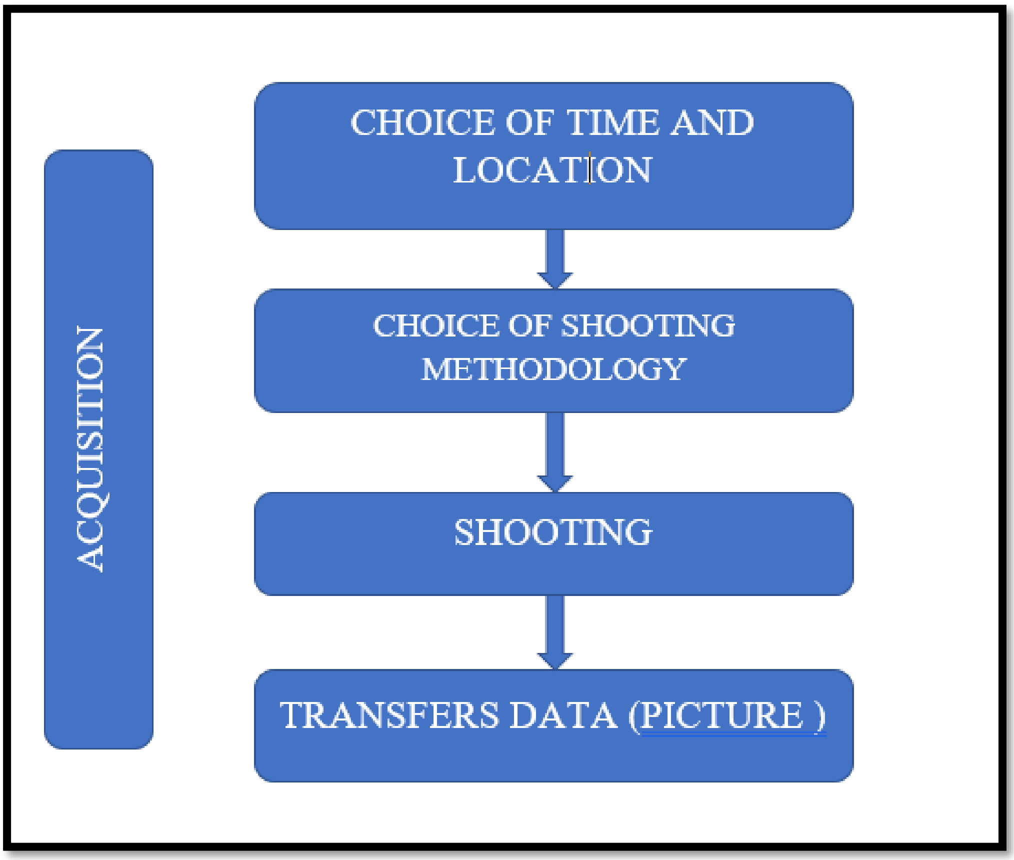


Figure 67: Acquisition tasks.

3. Treatment:

This is the last phase after data transfer. we start the processing by the delimitation of objects in each photo.

Then we make spatial relation between analogic points detected visually on the photos. Photomodeler offer an automatic matching option; but it's depended on the complexity level of the objects.

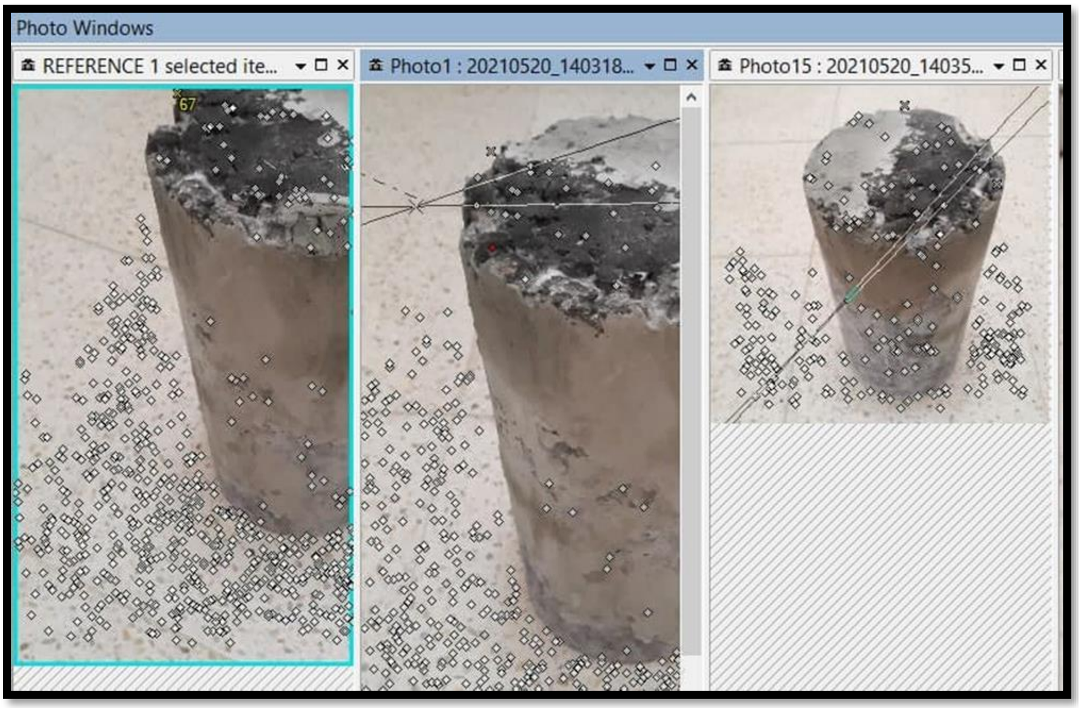


Figure 68: Treatment phases in software.

The generation of the digital surface model (MESHING OPERATION). It consists of the generation of THE TRIANGULAR IRREGULAR NETWORK (TIN).

Figure 69: : Treatment phases in software.

Once done we launch densification operation, interpolation between triangulated points.

Figure 70: Treatment phases in software.

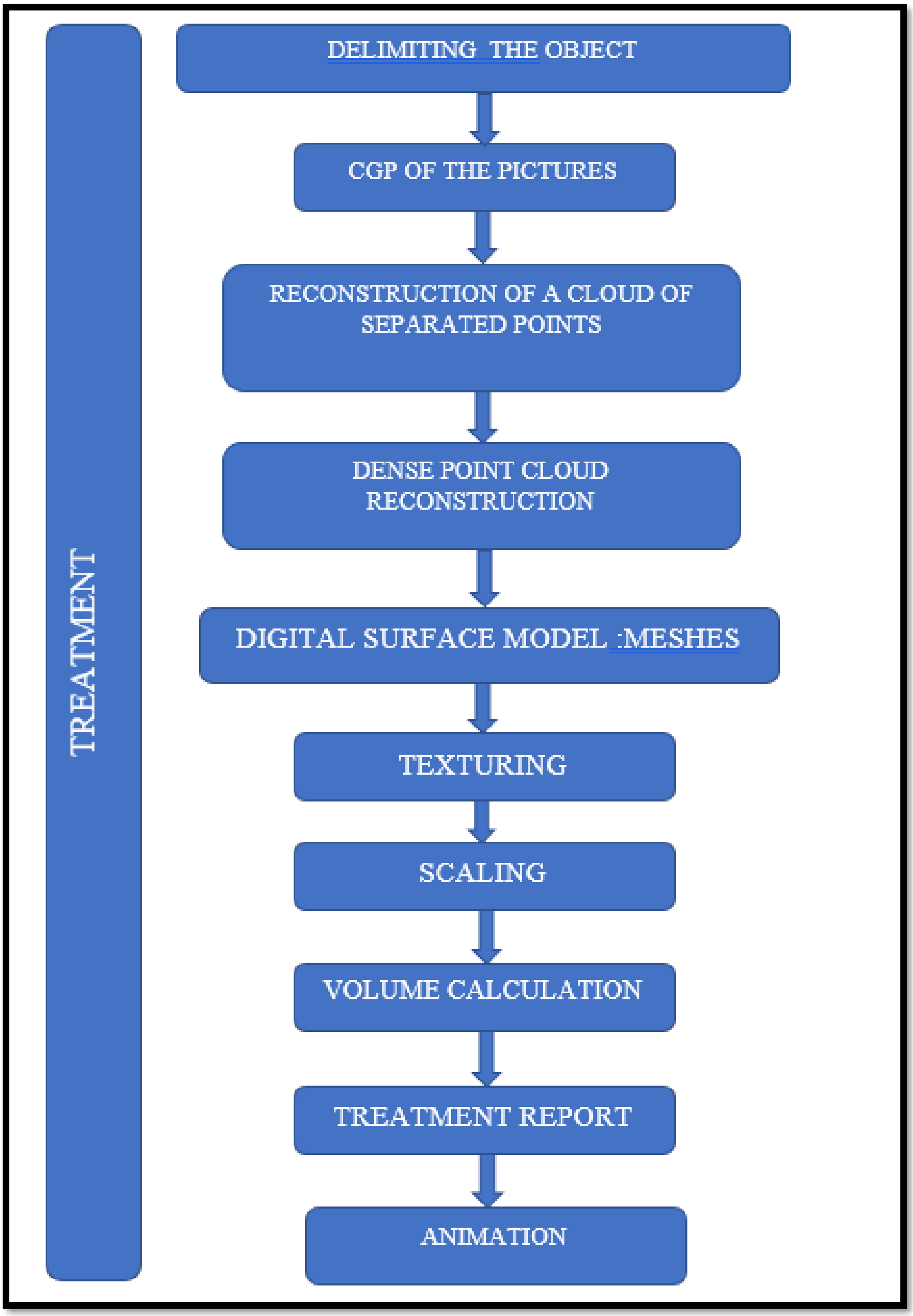


Figure 71:Treatment tasks.

V. RECONSTRUCTION STEPS IN SOFTWARE:

1. Sparse Point Cloud:

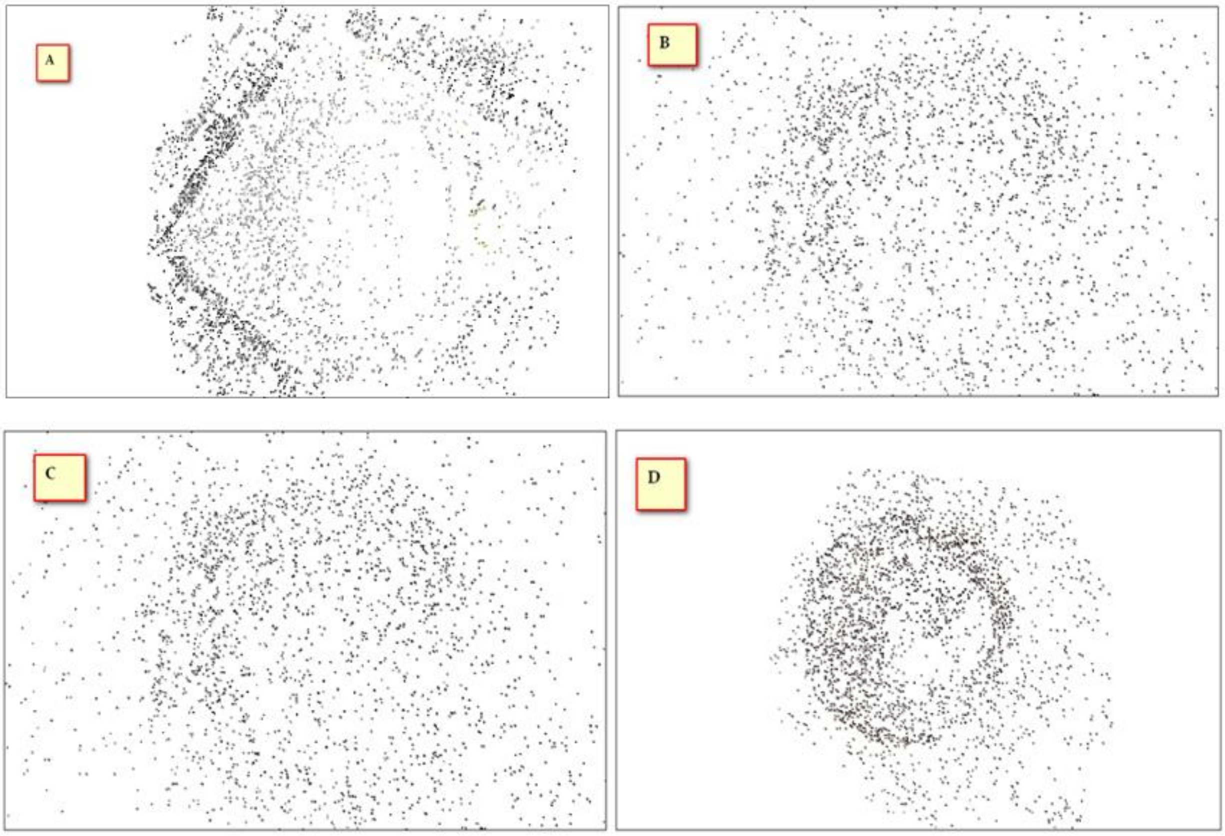


Figure 72: Sparse Point Cloud of reconstitution (A) sugar, (B) Gravel, (C) Send, (D) Cylinder.

2. Dense point cloud :

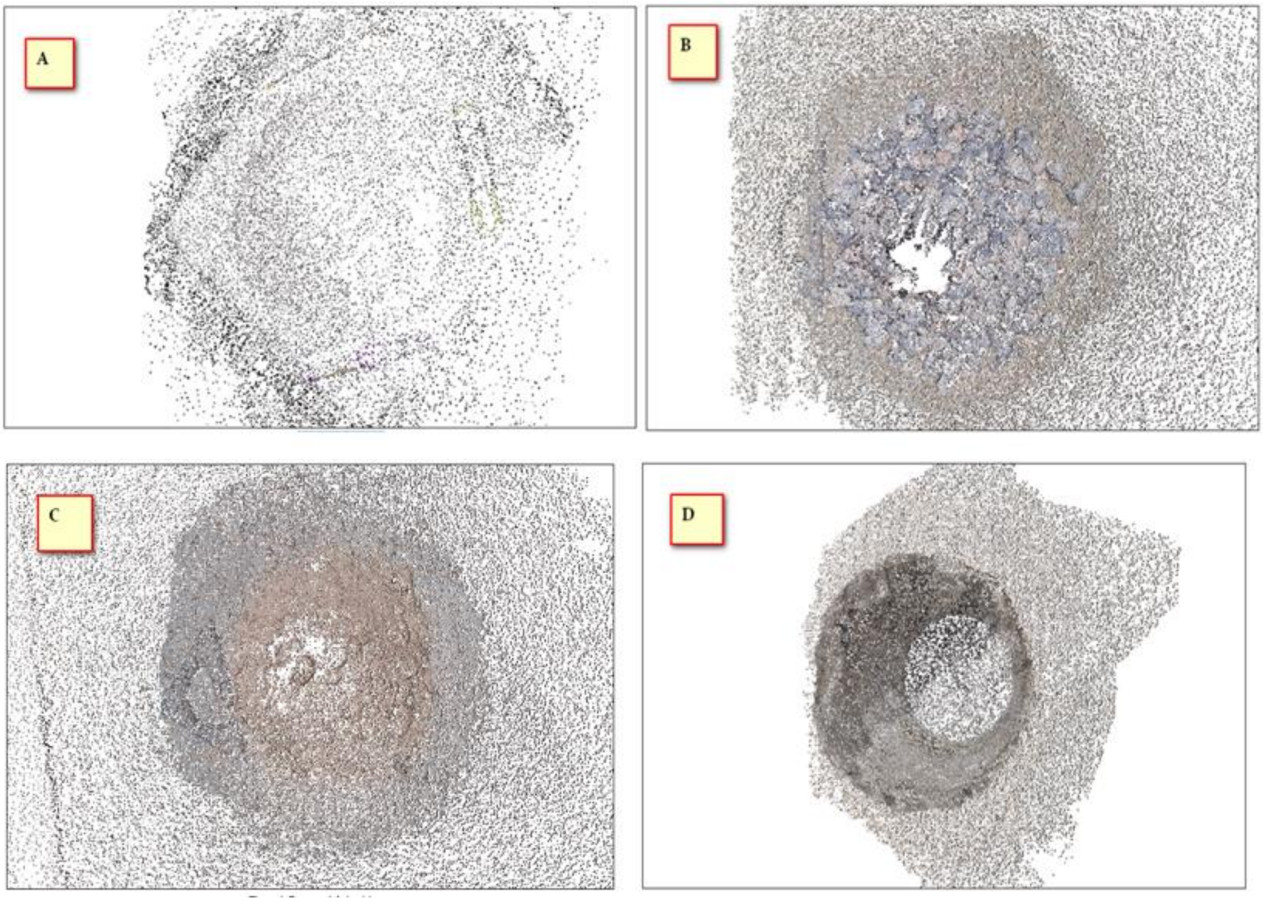


Figure 73: Dense point cloud of reconstitution (A) sugar, (B) Gravel, (C) Send, (D) Cylinder.

3. Mech :

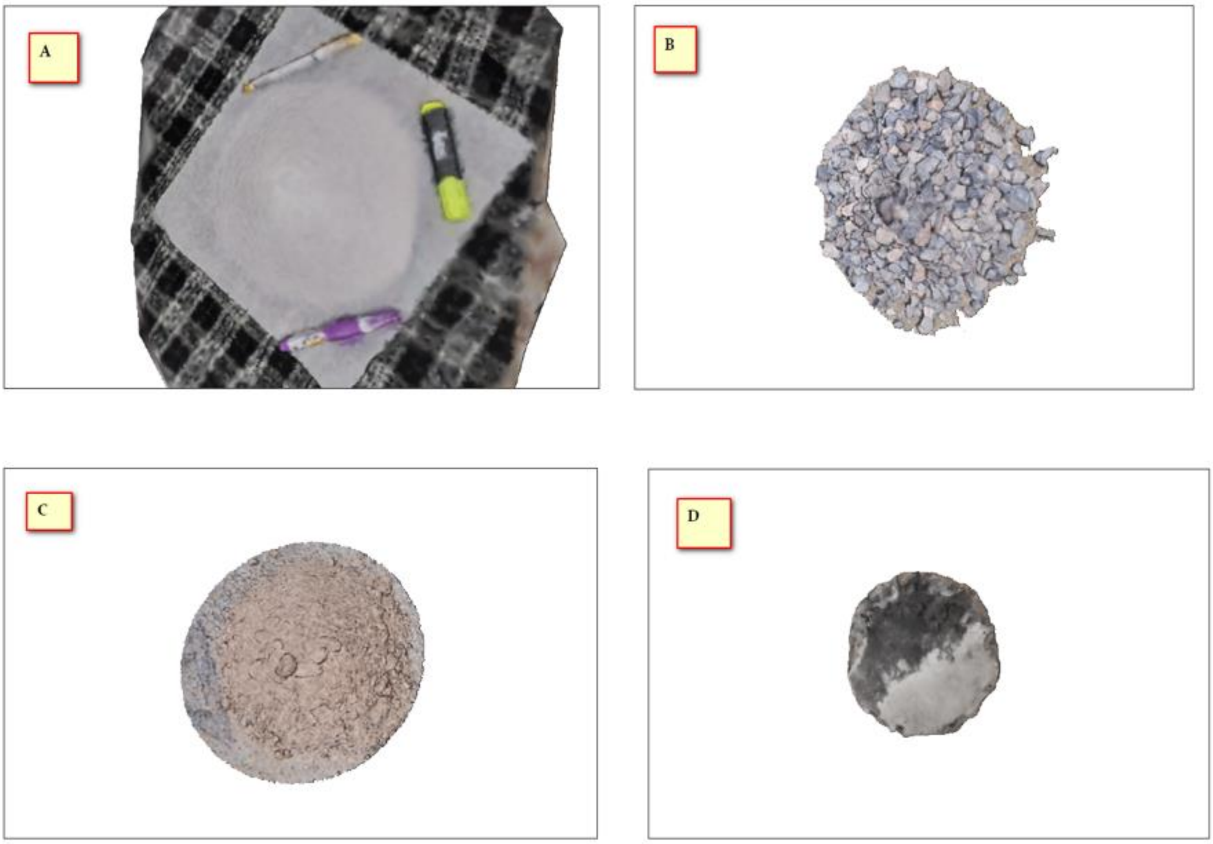


Figure 74: Mech of reconstitution (A) sugar, (B) Gravel, (C) Send, (D) Cylinder.

4. Mech volume :

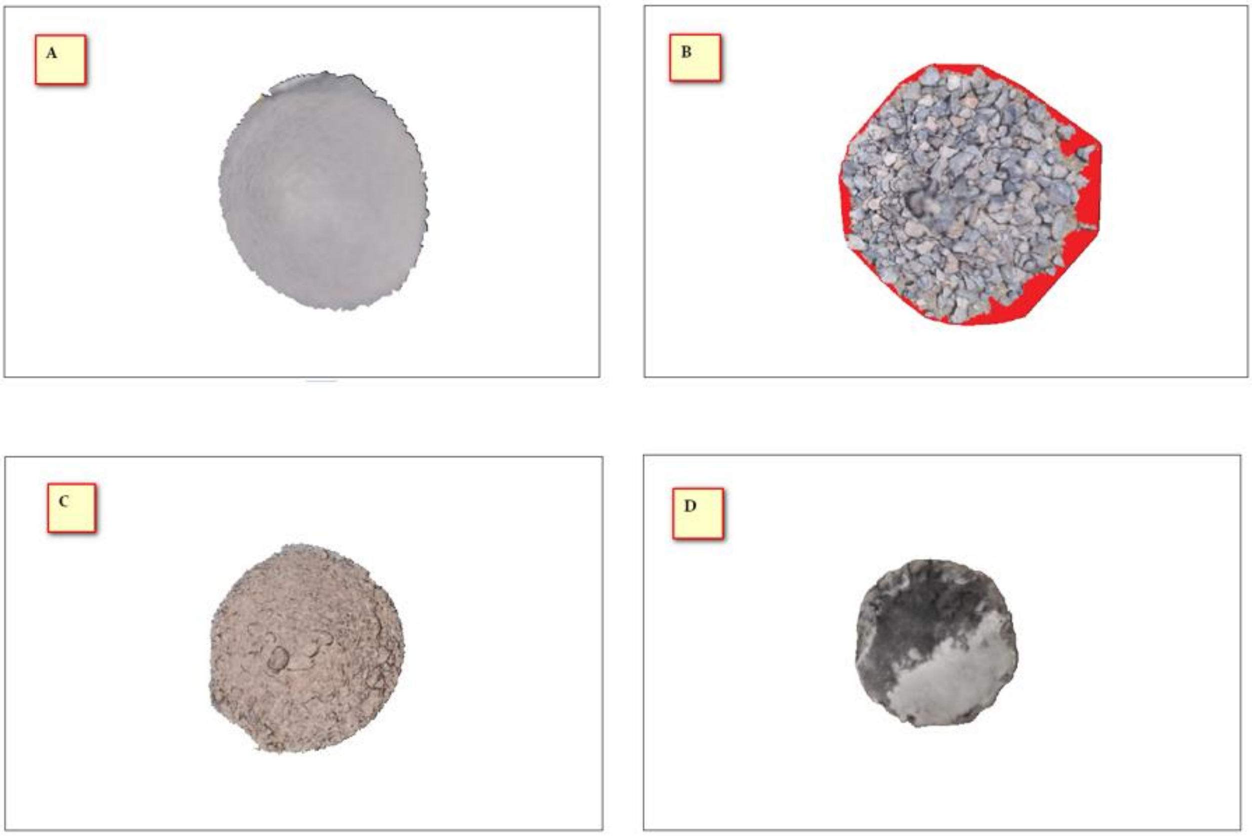


Figure 75: Mech volume of reconstitution (A) sugar, (B) Gravel, (C) Send, (D) Cylinder.

5. Textured mech:

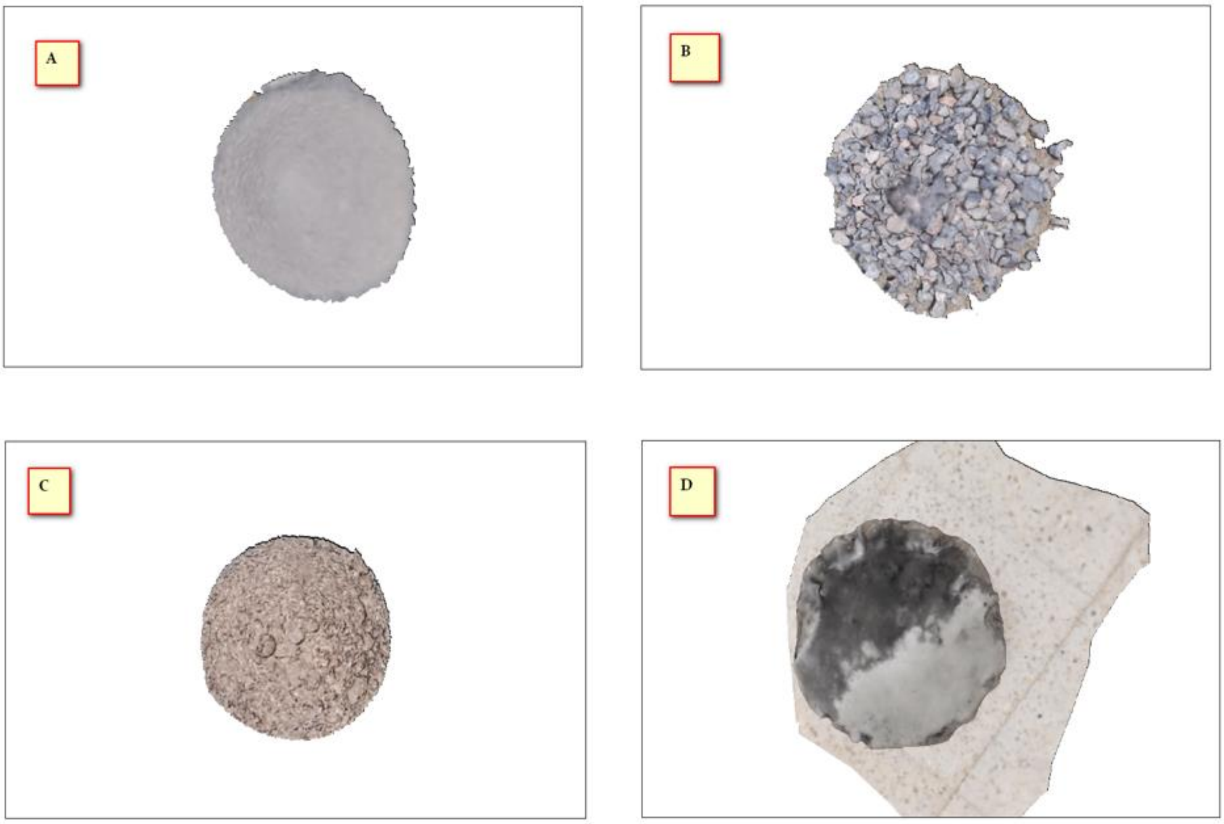
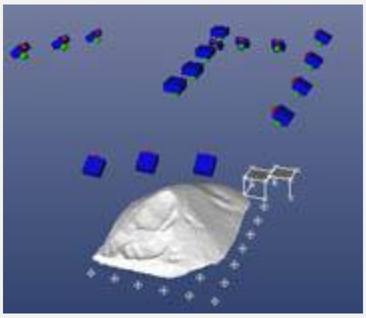
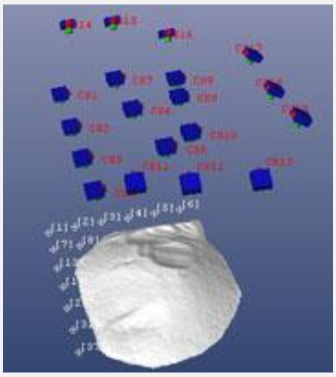
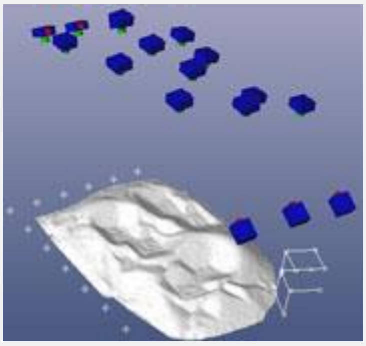


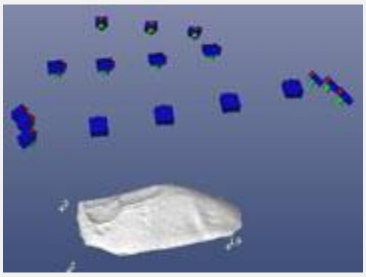
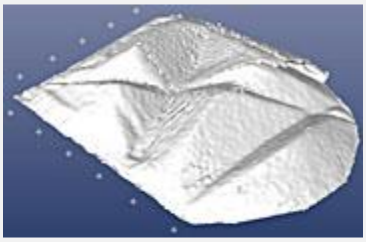
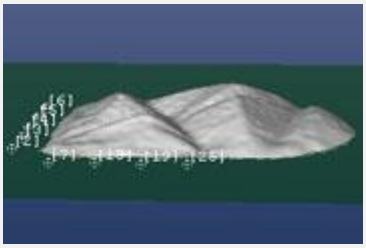
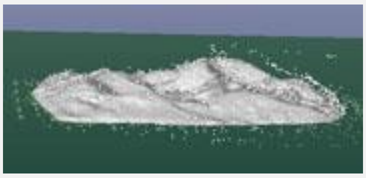
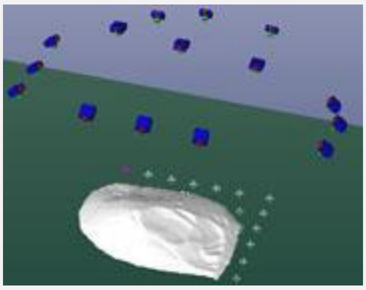
Figure 76:Textured mech of reconstitution (A) sugar, (B) Gravel, (C) Send, (D) Cylinder.

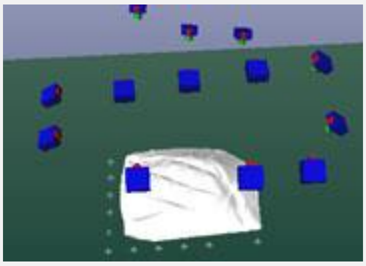
VI. OTHER PROJECT RESULTS :

The experimental results are summarized below. Each row shows one PhotoModeler project for one experiment and the resulting volume measurement, the volume error and a short summary:

Table 2: Other project Results.[40]

3D Viewer Screen Capture	PhotoModeler Calculated Volume over XY Plane	% Difference to 400 cm^3	Notes
	405 cm^3	1.25% over	Nikon D7100, excellent DSM result, little noise, varied pile shape.
	387 cm^3	3.25% under	iPhone 4 camera, some blur in images.
	380 cm^3	5% under	iPhone 4, flatter pile.

	407 cm^3	1.75% over	Nikon D7100, manually marked scale points.
 	598 cm^3	50% over	iPhone 4 camera, noisy pointmesh, overlapping triangulated pointmesh (visible in lower screen capture), big residual on scale points (suggests poor orientation).
	377 cm^3	6.75% under	iPhone 4 camera, images from automatically extracted video frames.
	368 cm^3	8% under	Nikon D7100, manually marked scale points, depth of field causes blur in portions of images, noisy point mesh.
	416 cm^3	4% over	iPhone 4 camera, some blur in images, relatively high residual for scale point (11) suggesting

			sub-optimal orientation.
	426 cm^3	6.5% over	Canon SD 1000, some blur results in pointmesh noise.
	408 cm^3	2% over	Nikon D7100, excellent DSM result, little noise, varied pile shape.

VII. RESULT AND DISCUSSIONS :

Table 3 : Summary table

Object	Knowing volume cm3	Measured volume by SfM cm3
Sugar	1000	1001.77
Sand	2000	2005.55
Gravel	2000	2002.03
Concrete cylinder	6380	6209

For a value calculated on Object, it can be seen that the calculated volume is always greater than the measured volume with a small margin.

We explained this according to our vision by the following points:

1- Quality of the reconstruction: We note that the reconstruction is done by smoothing for objects of rectilinear shape; however, with the smoothing of the program the volume increases;

2- pointing accuracy of the CGP; pointing with the mouse on a 2D object is easier and more precise on the contrary the 3D object is more difficult and incorrect;

3-the difficulty of dissociating of an Object from his environment, which should not be included in the volume calculation; the existence of some pixels belonging to the environment surrounding the Object induces their modalization by triangulation when calculating the Object volume which always generates an additional volume

4-the resolution quality of the device uses.

5- the validation of the results was compared to a volume calculated theoretically; and not measured by another precise technique for example the cylinder has a theoretical volume which is $\pi R^2 H$ however the value of H and the R were taken from the standard values used in the laboratory were for we don't measure the real cylinder

In addition, we judge that the results obtained are very satisfactory because the quality achieved is more than 97% precision.

Determining less than 3% error helps us in the future volume calculation (error subtracted).

.

CONCLUSION:

To conclude this research, we would like to clarify definite points on the objective of our research results obtained to present the perspectives at the end.

Indeed, the objective of this work is to offer a quality indicator on the volume measurement by using a terrestrial photogrammetry on objects that have not exceeded 2000 cm3 in volume using with ordinary camera of a mobile phone after its calibration of course.

The target objects were chosen by their differences in physical nature, their difference in color and aggregate.

Following the results and discussion above, we can confirm the reliability of using this technique and instrument for objects of similar sizes.

In perspective, this technique can be applied for the calculation of embankments and excavations on the ground after a study with the validation of quality measurement in comparison with the topographic instruments used.

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ANNEX

PROCESSING REPORT

OF CYLINDER

Concrete Cylinder
Structure and Motion
Project Data

Control Points

Name	X	Y	Z	Visible Cameras	Error (pixels)
GCP 1	5.869855	-2.848228	36.105907	0	N/A
GCP 2	9.557544	-3.278840	3.809503	0	N/A
GCP 3	-9.688199	-4.486137	34.321734	0	N/A
GCP 4	-3.217696	-9.901443	35.128909	0	N/A

PROCESSING REPORT
OF THE SEND

Structure and Motion

Project Data

Control Points

Name	X	Y	Z	Visible Cameras	Error (pixels)
GCP 3	-5.567517	-10.005639	6.084690	0	N/A
GCP 4	-10.861035	8.162764	4.385335	0	N/A

PROCESSING REPORT OF THE SUGAR

Structure and Motion

Project Data

Control Points

Name	X	Y	Z	Visible Cameras	Error (pixels)
GCP 1	15.958720	7.116955	12.509849	0	N/A
GCP 2	18.058415	-3.558598	14.129678	0	N/A

PROCESSING REPORT OF THE GRAVEL

Structure and Motion

Project Data

Control Points

Name	X	Y	Z	Visible Cameras	Error (pixels)
GCP 1	-17.644579	7.445107	4.085484	0	N/A
GCP 2	-17.608778	-11.231400	3.726042	0	N/A
GCP 3	-11.373446	-18.039295	5.177061	0	N/A