WORKFLOW DATA COLLECTION OF EXISTING BUILDINGS BY 3D SCANNING PROCESS (in modelling BIM)

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AUTOR:

ANDRES FUENTES CRUZADO

TUTOR ACADÉMICO UPV:

MARIA BEGOÑA FUENTES GINER

UNIVERSITAT POLITÈCNICA DE VALÈNCIA

ESCOLA TÈCNICA SUPERIOR ENGINYERIA D'EDIFICACIÓ

ETS d'Enginyeria d'Edificació

Universitat Politècnica de València

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PREFACE

Objectives of project

In this project, I have the objectives stated bellow:

- Understand the process how the 3D laser scanner technology - an high-tech data collection technology - has arrived into architecture history

- Get to know how to use and apply that new technolgy on the field of architectural and professional design

1. INTRODUCTION

1.1. TOPOGRAPHICAL PART: The existing data collection throughout the history of buildings

In ancient times, the surveyors through the centuries have made their measurements with a rudimentary instrumentation.

Going back around the year 3000. BC the Babylonians and Egyptians used ropes and chains to the distance measurement.

To 560. C. there are not references of new instrumentation until Anaximander introduced the "Gnomon", although it is believed that this could get you some reference of the Babylonians and Egyptians. Among the first users of this new instrument find Meton and Eratosthenes to determine the north direction and the circumference of the earth respectively.

The "diopter" (fig.1) or horizontal plane for measuring angles and leveling had his principle in a tube "U" with water which served to flatten the platform

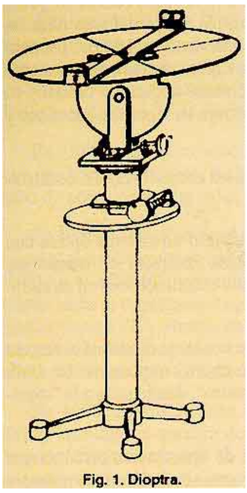


Fig.1 Diopter

The "corobates" or first approximation of a level, was a horizontal rule with legs in the four corners at the top of the rule where a groove was poured water for use as a standard.

For vertical angles, the rules of Ptolemy were used until the Middle Ages.

Roman, Greek knowledge carriers in Europe, used the "Groma", which consists of an eccentric cross with sinkers at their ends, fixed to a vertical bar.

Precision measurements steps are followed by step counters.

Vitruvius was also the builder of the first squadron applying the foundation of Pythagorean triangle.

Much later, the Arabs based on the knowledge of the Greeks and Romans used astrolabes divided into 5 arcmin.

About the year 1300, described by Levi Ben Gerson, a mechanism is known for indirect measurement of distances [Jacob's bar], by movement of a bar perpendicular to another main graduate, which provided and the parallactic angles.

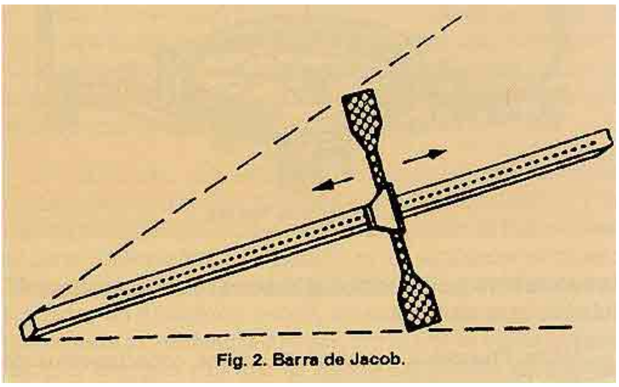


Fig.2 Jacob's bar

Compass from birth with Chinese reference to Alexander NECKMAN 1187, with the subsequent development introduced by Leonardo Da Vinci and Schmalcalder became the forerunner of the theodolite.

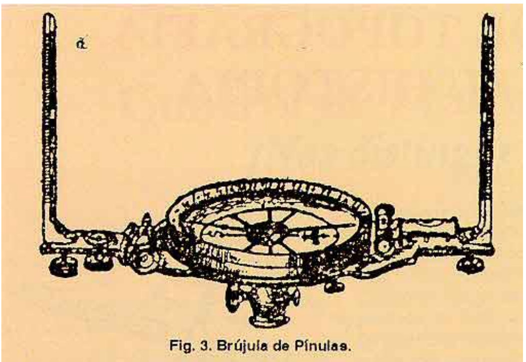


Fig.3 Pinula's Compass

The next step towards improving current **goniometer** (Instrument used to measure angles) was introduced by Josua Habernel with theodolite-compass dating from 1576. John Sisson built in 1730 the first **goniometer**

Fig.4 Goniometer

In 1720 the first **theodolite** (Precision surveying instrument for measuring angles of different levels) as such was built, this came equipped with four footscrews

Fig.5 Theodolite

About 1740 the first **double square**, built by mechanical Adans appears.

Since 1765 hard tackles market "**planchets**" (Surveying instrument to lift flat on the ground consisting of a board covered with drawing paper, mounted horizontally on a tripod and having a rule with visor, on whose surface are drawn in pencil visual targeted at different points of the field) with more or less differences on known until some years ago

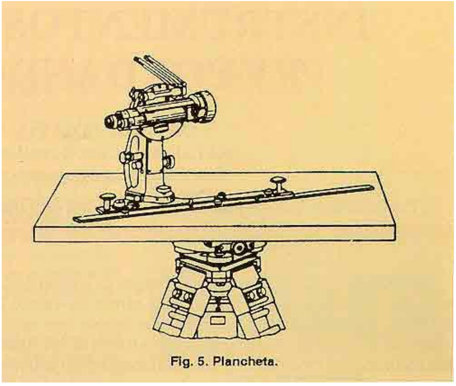


Fig.6 Planchets

In the construction line of self-reducing devices found in 1866 to Sanguet with **clisímeter** or slope gauge, which allowed to obtain the reduce distance with a minimum calculation

Fig.7 clisímeter

Adrien Bordaloue, around 1830, manufactured the first looks leveling fact that potentiate the study and manufacture of self-reducing, allowing read in the crosshairs the reduced distance and the term "t"; among these devices we can mention in 1878 the logarithmic tachymeter, in 1893 taquímetro autorreductor of Hammer

Studies and attempts were made to obtain the first automatic level, having to wait until 1946, year in which the Russian Stodolkjewich implemented these beginnings. In 1950, Carl Zeiss Ni2 manufactured the instrument that had a mechanical compensator instead of tubular bubble, precursor of current systems gravity compensation. Askania transferred this principle to theodolites in 1956 riding the compensator for vertical limbo.

The first electro-optical distance meter was manufactured in Russia in 1936.
Until 1968 will not appear the electro-optical distance meters laser. Wild manufacture the DI-10, distancer of small dimensions, which together with a theodolite provided a great benefit for topographic measurements, both speed and precision.

From this time, progress has been nothing short of dizzying. More or less 11 anos appeared semi-stations, which were a distance meter mounted there on theodolite, sharing housing with it (not very different in appearance to the current total stations), but with the theodolite was analog, the electronics could only know the results of the distance measurement, must hand typing angles so that the unit could perform calculations desired.

With the advent of electronic systems for capturing angles, the race against time has been even faster and more effective, obtaining digital theodolites more accurate than once and even lowering market prices.

Electron capture angles, both in incremental version as absolute, we spent almost without realizing the design of the current total station, improving reading angle and distance measurement

The next step that improves data capture are data collectors, gradually appearing external manifolds (notebooks with own software managed the operation of the station), collectors registration cards (the which they are handled by the station and its internal software), in its version of physical contact with the station or charging by electromagnetic induction, such as
inmates at the station, collectors must connect this to your computer for discharge. It will not take long for the technique allows data dump through a "modem" to the telephone line, the collector being hundreds of kilometers the computer that receives the data.

We can not forget that distance meters operate by themselves and phase measurement (And allowing completely flat reflectors) or per measure of time, which allows to read the distance to a solid, provided that this is not a material that absorb the emitted wave.

We can refer here to the latest models of motorized stations, in two versions, both stakeout points (which by introducing the coordinates of the points in the device, it is oriented and is marking the address in absence of read distance) and which through a system robotized
search and tracking the prism may be taking data without operator handling the total station, but the person carrying the reflector itself is contact the station giving few orders specifying the device

1.2. GRAPHIC PART: The graphic and non-graphic representation of information of existing buildings

1.2.1 From past to present

Just 25 years ago, almost all the drawings were executed using pencil and paper. When needed changes, it was necessary to erase and redraw. If the change was important, all the drawing was repeated. If a change affecting documents had to hand pick each of them and modify them.

Computer-aided design (Computer Aided Design-CAD) has modified this method of work, improving the way they are performed design tasks. Being originally 2D drawing tool, it has evolved over time to the intermediate stage of 2.5D to 3D phase and virtual reality (VR).

The benefits are not limited to obtaining a powerful drawing tool that improves quality and productivity, but other benefits are also obtained. In parallel to the development of the applications of computer-aided design, they have also developed other simulation, modeling and manufacturing of products. This evolution has been parallel to increase processing capacity and ease of use of computers, advancing remarkably since the arrival of the PCs.

This paper shows a perspective of the evolution of the computer (CAD) design over time and try to give a projection of future with special emphasis on applying them to the development of engineering projects.

1.2.2. Historical development of cad systems

The CAD has been a milestone for the field of engineering, architecture and construction, especially since it eliminated the need to draw plans by hand, allowing also incorporate changes easily. In addition, the CAD has provided a relatively simple tool for 3D visualization. Manual processing of 3D perspectives yesteryear was based on slow and laborious techniques of drawing, which also were not interactive. The CAD has changed, therefore the nature, definition and scope of the design process. Here is a brief history of CAD, since the early '50s, when it appeared the first graphics program, until the early 90s.

Before 1970. The first CAD data from the 50 to the US Air Force. The first set of graphics, the SAGE (Semi-Automatic Ground Environment) air defense system, which was used to display radar data. In the 60s, CAD systems were used to design interior spaces of offices. 1968 were already available in 2D CAD (very basic, as we understand it today) systems. These systems worked on mainframe terminals (mainframes).

70s. Earlier this decade, several companies began offering design systems / computerized drawing. Many of the products and firms best known today had its beginnings in this period. Some of these names include CATIA and CADLink. They could already be some 3D capabilities in calculation programs HVAC (Heating, Ventilation and Air Conditioning). In the late 70s a typical CAD system consisted of a mini-computer 16 bit with up to 512Kb of memory and 20-300 MB of hard disk.

80s. Autodesk creates a CAD program that works on a PC. Autocad soon became the most popular CAD program. Many other programs from different companies followed the same path. During this decade, CAD programs were used primarily for engineering developments. Start the (Geographical Information Systems) developed GIS systems.

90s displays are widespread in 3D. Autocad Release 12 becomes the CAD program on Windows Top sellers. A mid-90s appear many CAD programs for a variety of uses and applications. In the late 90 many people already use CAD programs regularly, but there is still a struggle to attract the attention of users. The best programs are developed to meet the growing needs of the industry. Many simple CAD programs are also developed. 3D CAD programs abound in the market. Verticals solutions are offered providing specific solutions for each of them (construction, civil engineering, mechanical and manufacturing, etc.)

1.2.3. Virtual Reality (VR)

The VR goes beyond the flat panel monitor, takes us into a three-dimensional world. Psychological and perceptual difference is that stop looking out of a window (computer monitor) and becomes within the virtual stage.

These definitions describe the three fundamentals that differentiate RV other concepts with which it is commonly confused:

- Realistic simulation of real-time environment: the RV should make us feel the environment (sight, hearing, etc.) as if it were real. This includes, of course, that the creation of the three-dimensional virtual environment must be in real time, something not previously recorded.
- Immersion: the VR system must immerse ourselves in the virtual world, making us feel that we are really inside part of the scene.
- Implicit Interaction: Like the real world, the virtual world must respond to our stimuli. For example, the display should change automatically with the movements of the participant, without any explicit order. The revolution of the RV in the man-machine interaction is that the user forgone the computer to pass directly interact with the scene.

These three properties of RV involve three basic elements of fact project. Exceeds the virtues of the traditional model. Allow distribution processes in three dimensions plant, incorporating and verifying the results of design and can be modified interactively. All this is also extensible to product development.

1.2.4. Augmented Reality (AR)

Augmented reality is a technology in which the vision that the user of the real world is enhanced or augmented with additional information generated by a computer model. The improvement may consist of virtual devices placed in a real environment, or the display of "non-geometric" information about real objects.

AR allows the user to work and examine 3D real objects, while receiving additional information about these objects. RA adds information to the real world of the user. It allows the user to stay in touch with the real environment. This is a clear difference with the VR, where the user is completely submerged in an artificial world, completely separated from the real world. In VR systems there is no possibility that the user interacts with objects in the real world, the RA, however, does allow users to interact naturally with a world that is a mixture of virtual and real . The AR systems have the computer user to the real world, while VR systems have the real to the computer world.

However, these applications imposes very stringent requirements. To combine models actually states that these models are very accurate. This requires realistic mix objects are introduced into the actual scene behave in a very realistic way. To achieve this reality requires the RA a very detailed description of the physical setting.

CONCLUSIONS OF THE DEVELOPMENT OF THE CAD SYSTEMS

The introduction of CAD data of the 80s quick replacement of the drawing boards by computer screens occurs. This is essentially due to two reasons: 1) the programs become more powerful and easier to use simultaneously, and 2) the price of both the PC and the CAD program enters a threshold of accessibility. CAD systems help not only more accurate, better drawn and easier modification, thereby improving the productivity of the project documents. But also and very importantly generate flows of information to other phases of the project and a clear improvement of the design. CAD systems today occupy a prominent engineering companies in place, forming a technological capital.

The development of computer technology in recent years has caused a fundamental change in how to conduct and manage projects. Management and communication of information and knowledge. In planning and project management. In the 3D visualization. The color revolution.

Progress has been made in systems design and computer-aided engineering in the phases of design, detail and analysis, improving project performance, and shortening times. They are developing new ways for communication of data and knowledge. But the RV and RA present new opportunities to advance the creative capacity of the project fact, to simulate a virtual scale than projected. This should lead us to choose and better define the solutions adopted, and to integrate the new requirements (safety, environment, etc.) the fact project

2. STATE OF THE ART

2.1. 3D laser-scanning equipment

The laser scanner is a terrestrial acquisition device mass data reporting we three-dimensional point cloud generated from measuring distances and angles, using a laser light beam.

Fig 8. Laser scanner

Basically it is a topographic reflectorless measuring station, which performs mass observations on pre-selected areas. It also has incorporated the cameras, which record the information of the visible range, which provides an infinite object information.

This is a developing technology, which can be considered the future in the world of Topography, where its operation is similar to the a

forementioned LiDAR, with the difference that it, is mounted on a tripod in most cases, being its more limited in area use.

The potential of this technology is very high, obtaining measurements, a massive amount of data where everything that exists in reality be represented by three-dimensional points.
The problem to determine therefore the precision and scale of the project to develop, because there reside the type of device that will choose.

Surveying two types of laser sensors are distinguished primarily used:

- Short range, used especially in close and limited size objects. It is used in Industrial Surveying and restoration of statues, or accidental traffic studies

Fig.9 Laser for short range

- Long range, where we find a less accurate because of the distance. They are mainly used in volume calculations, restoration of facades, etc.

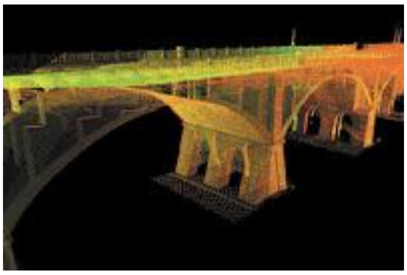


Fig.10 Laser for large range

It should be noted that the greatest difficulty will lie in the unification and cleaning of the data obtained from the registration in the different positions taken, which will form the 3D model of the particular object.

This is the characteristics of the lasser scanning that we are going to use:

Laser scanner for fast and exact indoor and outdoor measurements in three dimensions: Simply at your fingertips

The smallest and lightest laser scanners on the market - Focus^{3D} X Series are ideal tools for indoor and outdoor applications. The fast and accurate laser scanners Focus^{3D} offer everything you might expect from professional 3D laser scanners – with FARO's established and well-known level of simplicity.

Focus^{3D} X 330 offers extra long range - 330m, Focus^{3D} X 130 is a mid-range device offering precise scanning up to 130m. The Laser Scanner Focus3D X30 was specially designed to fit the need of short-range and interior scanning applications. The Focus^{3D} X 30 captures data up to 30 meter.

Fig.10 Lasser scanner used

All scanner types offer the possibility to perform scanning even in bright sunlight. Remote scanning as well as almost limitless scan data sharing via SCENE Webshare Cloud make the laser scanning solution truly mobile.

Features of the Focus^{3D} laser scanner

FARO Focus^{3D} laser scanners are revolutionary, non-contact devices for 3D modeling and documentation that can be operated simply and intuitively via an integrated touchscreen display. In addition to the touch interface, features such as its minimal size and weight make the Focus^{3D} easy to use and allows you to save up to half the scan time compared with conventional 3D laser scanners.

- Range Focus^{3D} X 30: 0.6 – 30m
- Measurement speed: up to 976,000 points/second
- Ranging error: ± 2mm
- Laser class: Laser class 1
- Weight: 5,2kg
- Multi-Sensor: Compass, Height Sensor, Dual Axis Compensator
- Size: 240 x 200 x 100mm
- Scanner control: via touchscreen display and WLAN

Fig.11 tripod used

2.2. The data collection equipment Laser-Scanner 3D: requirements, procedures, options, which store information, support information, etc.

There are multiple ways to collect 3D data but two of the most common methods (and the two most frequently used by Direct Dimensions) are laser scanning and digitizing.

During laser scanning, a laser line is passed over the surface of an object in order to record three-dimensional information. The surface data is captured by a camera sensor mounted in the laser scanner which records accurate dense 3D points in space, allowing for very accurate data without ever touching the object.

Laser scanners can be broken down further into types such as laser line, patch, and spherical. The FARO ScanArm, the FARO LS, the Surphaser, Konica Minolta Vivid 9i and Range 7 are some examples of laser scanners that we often use at Direct Dimensions.

The second major method is digitizing, which is a contact based form of 3D data collection. This is generally done by touching a probe to various points on the surface of the object to record 3D information. Using a point or ball probe allows the user to collect individual 3D data points of an object in space rather than large swathes of points at a time, like laser scanning. This method of data collection is generally more accurate for defining the geometric form of an object rather than organic freeform shapes. Digitizing is especially useful for industrial reverse engineering applications when precision is the most important factor. Stationary CMM's (coordinate measurement machine), portable CMM arms, and the FARO Laser Tracker are all examples of digitizers that we often use at Direct Dimensions.

Other methods of collecting 3D data include white light scanning, CT scanning and photo image based systems. These technologies are being utilized more frequently in the field of 3D scanning and new applications are being discovered every day.

Because you are trying to collect the most accurate data possible, there are a few more things to keep in mind before you run out and start scanning everything in sight.

Bright light sources in the area, including the sun, can really mess up your scan data. At Direct Dimensions, if we are laser scanning an object outdoors we prefer to do it at night if able. Light can reflect off of your scanning object and create "noisy" data. This brings us to:

Very reflective materials generally do not scan well. This can be avoided with a light coating of white powder spray (or anything that dulls the reflectivity). There are also some scanner manufacturers who are actively working to solve this problem.

Fixturing: whether you are laser scanning or digitizing, it important that your scan object will not move while you are collecting data. The tiniest motion will cause inaccurate data.

Data management should be considered when planning the uprising begins. A laser scanner captures thousands of points per second and data sets become very large in a short time. For this, you need a computer capable of storing, processing and archiving data

To understand the data storage is necessary to know more file formats common to store data from a laser scanner. The file formats determine the accuracy and amount of information that can be stored in the file. Some formats save the coordinates with single precision floating (32 bits) point, while others do double-precision floating point (64 bits). When the coordinates are stored Euclidean relative or absolute points, this may not be important, but some scanners store data in polar coordinates. In polar coordinates, an increase of 0.01 degree angle It means an increase of 1 cm at a distance of 50 m. In this case, the accuracy of point Floating is very important. These differences must be taken into account when it makes a conversion between different formats.

Some formats only contains the point information (coordinates x, y, z), while others add more information like color or reflectivity, the normals of the points, the scanner position, etc.

The most common formats for storing point clouds are:

- DXF: AutoCad format.
- PTX: ordered text format Leica containing xyz coordinates, reflectivity and color. Sometimes also it contains the scanner position.
- PTS: text format Leica unordered containing xyz coordinates, reflectivity and color.
- XYZ: unordered text format containing xyz coordinates.
- XYZRGB: unordered text format containing xyz coordinates and values color (RGB) for each point

Since the laser scanner captures large amounts of data, they are taken many more points really necessary; although they can be used later. Therefore, it is very important to keep and archive data accessible by a long period of time. The fact archive data has become in itself a major problem, not only in the case of laser scanned.

When file, add metadata is very important to know what is scanned and how it is stored or processed. Metadata should be subdivided into metadata scanning project, registration and information support.

Metadata scanning:

- Filename and raw data.
- Date taken

Scanner system used (with the serial number of the manufacturer). Name of the company.

- Name of the monument.
- Monument's number (if known).
- Rising number (if known).
- Scan number (unique number for this survey).
- Total number of points.
- Density of points on the object (with distance reference). Terms

Weather during scanning (only scanned outdoor).

- Filename of an image, taken from the same point and displaying data take two. The name must be the same as the raw data file.

  Metadata project:
- File name (s) with raw data used in the registration.
- Shooting Date (month and year).
- System (s) used (with the serial number of the manufacturer (s) scanner.
- Company name.
- Name and number (if known) of the monument.
- Rising number (if known).
- Number of individual scans.
- Total numbers of scanneds.
- Total number of points.
- Filename with supporting data.
- Description of recording method (for example: "All scans are recorded about a local mesh using targets ").
- A guide plane to show data taken with named individual points.
- weather conditions during the survey (only scanned outdoor)
- Any other specific information.

  Registration information (for each parking scanner):
- Traslacions in the X, Y, Z needed to transform the original scan to the scanner position.
- Rotations around the X, Y, Z should be made in the order X, Y and Z.

Supporting information:

- point ID, X, Y, Z, σDX, σDY, σDZ, comment (optional)

2.3. The information processing 3D cloud points and incorporating information from the point cloud BIM modeling programs:

Once generated point clouds, a study on the file formats supported by different applications, summarized in the following table:

Apliccation	Import/open	Export/save	
		Model	Cloud Point
Agisoft PhotoScan	-	obj, .3ds, .wrl, .dae, .ply, .dxf, .fbx, .u3d, .pdf, .kmz	obj, .ply, .txt, .las, .u3d, .pdf
Autodesk 123DCatch	-	.dwg, .fbx, .obj	-
Autodesk Recap	rcs, .fls, .fws, .lsproj, .ptg, .pts, .ptx, .las .zfs, .zfprj, .asc, .cl3, .clr, .e57, .rds, .txt, .xyz, .rcp, .pcg, .xyb		rcs, .pts, .e57, .pcg
Autodesk Photo on ReCap 360	-	.obj, ,rcm, .fbx, .ipm	.rcs
REVIT	.rcs, .rcp, .3dd, .asc, .d3, .clr, .e57, .fls, .fws, .ixf, .las, .las84, .mpc, .obj, .pcg, .ptg, .pts, .ptx, .rds, .rep, .rxp		

In this table we can see what format you can use in each case

From the above table it shows that the evolution of 123DCatch Autodesk, in this new version Autodesk Photo on ReCap 360 plus objects allows the export point cloud and is better integrated with Recap, professional application for editing Autodesk point clouds. In case that does not occupy, having generated point clouds with Photoscan, the file that best fits into the REVIT is the format, which also stores information obtained color images allowing viewing.

Revit for use in this type of files need to be preprocessed to be converted to a format .rcs, and this can be done directly from the program or ReCap application, which provides among others the following features of interest used:

- Import and merge several clouds of points in one file
- Get information and coordinates of points of the cloud, and measure distances and angles
- Organize the point cloud in different regions or views into layers that can be enabled or disabled independently
- Change the color mode with the cloud of points between RGB or color gradients is displayed (as reported height, intensity or normal values)
- Generate different bounding boxes for export other point cloud, smaller or different features to the original or (Fig.2).
- Select points by rectangular, polygonal or flat windows.
- Elimination of zones or unwanted items from the point cloud

2.4. The current modelling state of a building by BIM

Make 2D models directly from point clouds is a matter of interpretation human. Most programs in this area are modules of CAD packages like AutoCAD or Microstation. A special interface allows the user to load large clouds points in these programs for processing with standard CAD tools. Common programs to perform these tasks are: Leica CloudWorx, Kubit PointCloud, CAD Link ... LFM).

The cross-sections, plans and elevations can be generated by taking a fine cut Cloud points and projecting all those points on a plane. Then the user You have to draw manually or connect the dots to create lines, arcs, etc. The user It makes an interpretation of the corners and details smaller than the resolution of scanner. This is a difficult task and precise that it can take considerable time. The person carrying out this task must have a knowledge of the building or structure or have photographic material available to make the correct interpretations.

In some research centers they have been created algorithms to automate these tasks. Some of these algorithms have proven useful, however they need certain restrictions to give satisfactory results. This means you can not use of generically and therefore they are not yet implemented in commercial software

Elevations can be created in two ways. When there is information available about color, thanks to photographs or are available intensity values, points with color can be projected on a plane, creating a true orthophoto. Drawing on the orthophoto can be obtained elevations. With this method, the accuracy of lift depends largely on the scanner resolution.

Another way to create the elevations is important to trace the edges (windows, doors, etc.) of the 3D point cloud and 3D project these entities on a plane. This technique requires a good geometrical knowledge and ability to quickly recognize structures in point clouds.

Some programs allow you to register external images to the cloud of points and use them to monoplotear. Thus, the interpretation is made in the image and depth information of the point cloud is removed. The problem with such programs is that the result should be checked twice because by drawing an edge in an image is often misunderstood by the program because of missing data and therefore not generated in the correct position.
Common applications are:

- **3D direct modeling from point cloud**

When you know in advance how a 3D object and can describe geometric primitives, can automatically detect from the point cloud. When these geometrical shapes cloud points are set, the algorithm assumes that it is an ideal way. For example, scanning a petrochemical plant it can be easily converted into a 3D model assuming that all pipes have a circular section and the connecting pieces also have a specific form.

- **3D modeling of complex surfaces**

Generally, the end product of a process of 3D modeling of a mesh of the object surface. Connecting all points of the cloud with small triangles, a surface model or mesh is generated. This mesh is a three-dimensional interpolation points creating a complete representation of the surface. To create a model of quality,
must follow a series of steps:

- Cleaning data (noise reduction, elimination of gross errors ...).
- Resampling
- Meshing / Triangulation
- Disposal of empty (bypassing, joining ...)
- Optimizing mesh

- **2D modeling indirectly from point clouds**

2D modeling indirect means you can get 2D drawings from 3D modeling objects or mesh objects. This technique is useful when you have to do a lot of cross sections, for example a section to each centimeter to create a map with contour lines.
Indirect modeling requires a 3D modeling phase as described in paragraph 3.6.5. Once you have created a model, you can cut in layers to create cross sections. Interpolating areas between measured points is done automatically in the modeling phase and does not require to be performed by an operator.

3. Laser scanning in practice

Using a laser scanner in the capture of a building is not just push a button and wait the results obtained. It required a thorough understanding of the equipment and scanning process. Some process steps are fairly automatic scanning while others still require intense work. This chapter (fig 12) will discuss the terrestrial laser scanning process.

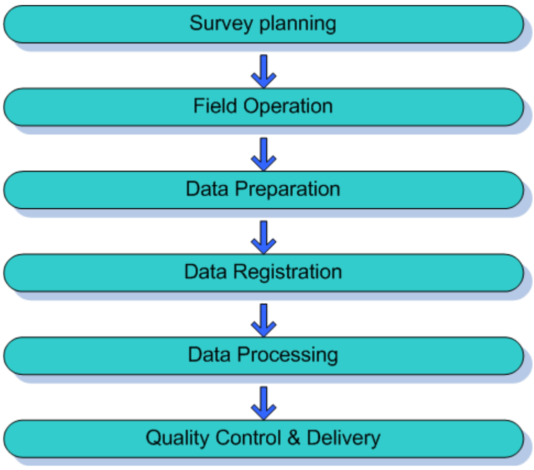


Fig.12 Workflow with a terrestrial laser scanner

3.1. Planning the process

Currently there is not standard process for planning a laser scanning terrestrial. However, planning must contain at least the following points according to the user community laser scanners:

- Determine the objectives.
- Analysis lift area.
- Determine measurement techniques and equipment.
- Data management.

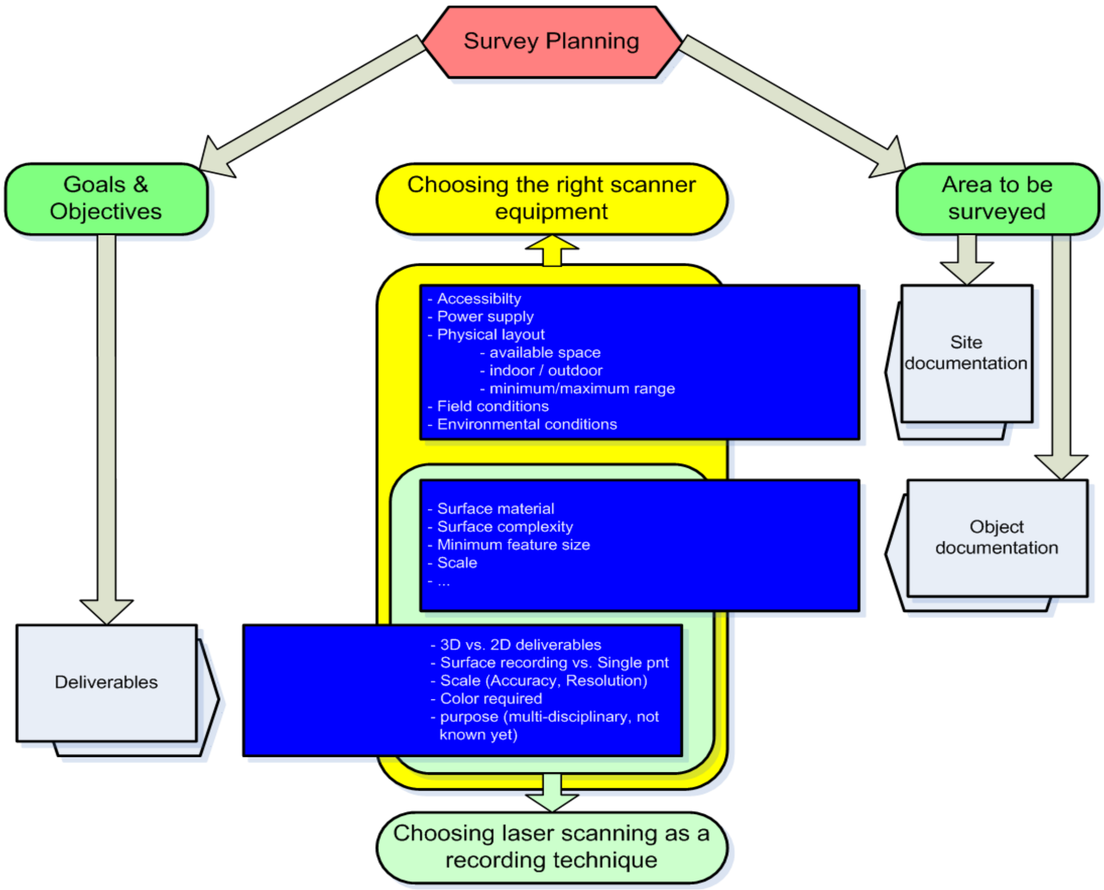


Fig.13 Diagram of planning

3.1.1. Analysis of the area to lift up

Collect the more better information about the object to document gives us an idea of the
complexity and the time required to perform the task. As already mentioned in the preceding paragraph, the required resolution and accuracy documentation are conditioned by the scale of the survey or by the entity minimum recognizable in the final product delivered.

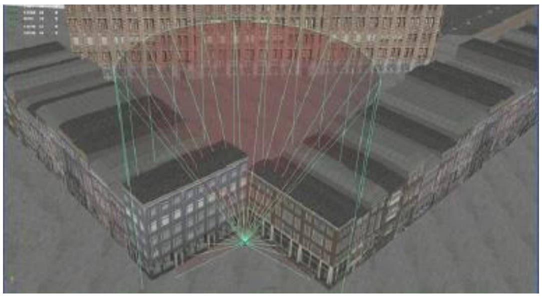
Not only we can provide useful information the building in question but also its surroundings. The place can be located in a place dispersed obstructions, limiting possible parking, or there may even be time restrictions to access the location (eg, in the works of the subway tunnels). Indirectly, possible locations laser scanner determine the minimum and maximum range the scanner must meet.

3.1.3. Determination of optimum laser scanner positions

After gathering the information of the site to document and chosen as laser scanning the best technique for this, you have to plan the location of the laser equipment scanner and reference points (Figures 29 and 31, respectively).

The optimal positions for parking scanner should be chosen so as to guarantee maximum coverage and accuracy and at the same time, the initialisation is minimized. The measurement accuracy depends on the diameter of the laser footprint, indicating that the angle of incidence and extent are of great importance to determine the scanner's position. In [26] described a detailed analysis to determine the optimal scanner settings to achieve the required accuracy.

The following list provides a set of priority rules to consider when optimal scanner position is determined



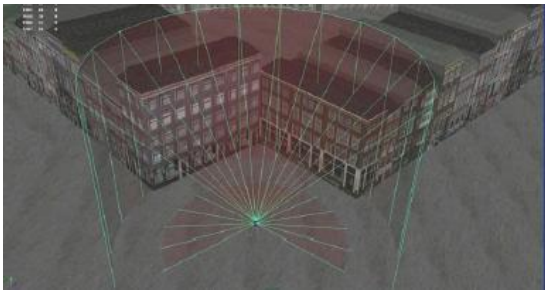


Fig 14 : (left) Bad scanner positioning: presents steep angles. (Right) Good scanner positioning

- Check that the positions cover the widest possible area without obstacles in the line of sight and the least possible shadows occur.
- Check that the minimum and maximum ranges are met to achieve the required accuracy. The greater the distance to the object, the lower the accuracy and resolution.
- Minimize the occurrence of small angles of intersection. Acute angles with the laser beam is not reflected as well, so the precision of the scanner is smaller.
- Try to reduce the number of parking

Other important factors to consider are:

- Occupational Safety and Health.
- The environment (vibrations, wind ...).
- lift the scanner on the ground.
- Visibility of artificial or natural points of reference.

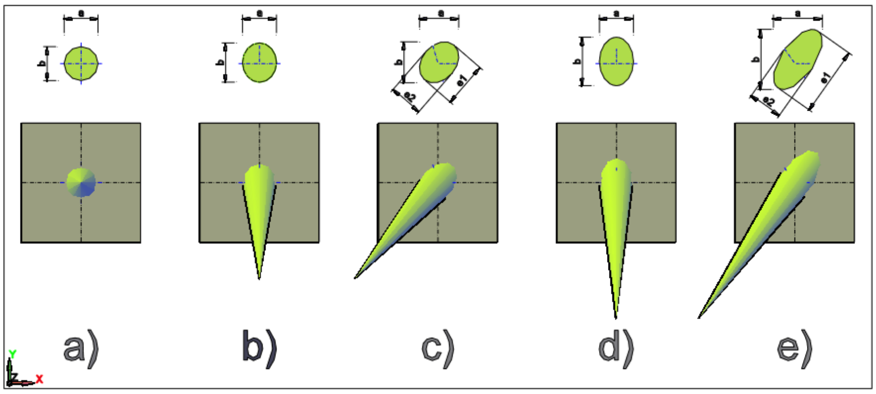


Fig 15: Traces of the laser when scanning with different angles

Along with optimal scanner positions, types of benchmarks and positions and / or geometric configuration are also important. The reference points are principally used to record scans made from different positions. There are currently a variety of targets available: retroreflective, spherical, paper, prisms ... In the future, there will be targets even with GPS receivers.

One of the most important points when targets are used is that they must be spread as widely as possible, not only in the directions of the X and Y axis but also in the direction of axis Z. This is often forgotten and all targets are simply placed on the floor (Fig. 31).
Some configurations of the targets do not produce a unique solution when the record is done. For example, if all the targets are in a line, we have a degree of freedom, rotation about that line.

Often scanners companies provide special targets retroreflective and spherical. These targets are designed to reflect most of the laser beam. The scanner can then automatically detect these targets and, after a higher-resolution scan to determine the exact center adjusting a primitive surface to measure the point cloud.

Sometimes paper targets because of their low cost are used. In other instances, a retroreflective prism is placed on the scanner. Knowing the distance between the scanner mirror and prism, you can determine the position of the scanner measuring the prism with a total station.

3.2. Field work

3.2.1. Preparation of uprising

The preparation phase includes lifting decision making technique registration to use. These techniques can be subdivided into three categories: registration by resection of scanned targets, registration by parking landmarks known and registration using point to point constraints.

3.2.2. Parking scanner

Parking a scanner generally follows a similar process to a total station. the following steps (Figure 33) are carried out:
tripod mount: the tripod opens and legs extend. Make sure the tripod is on steady ground.

- Normally, the scanner is placed at the height of the eyes. When the floor surface to be scanned has better a position higher because provides a better angle.
- Fasten the scanner to the tripod by placing on it and anchoring it.
- Depending on the recording technique, the scanner should be placed on a point known reference.
- Level the scanner. By varying the length of two of the tripod legs, evens the top surface using toric levels. The bubble must be within the circle inside. We must be as accurate as possible. When it is over the point reference, this procedure should not alter the point on which we were in the Step 3.

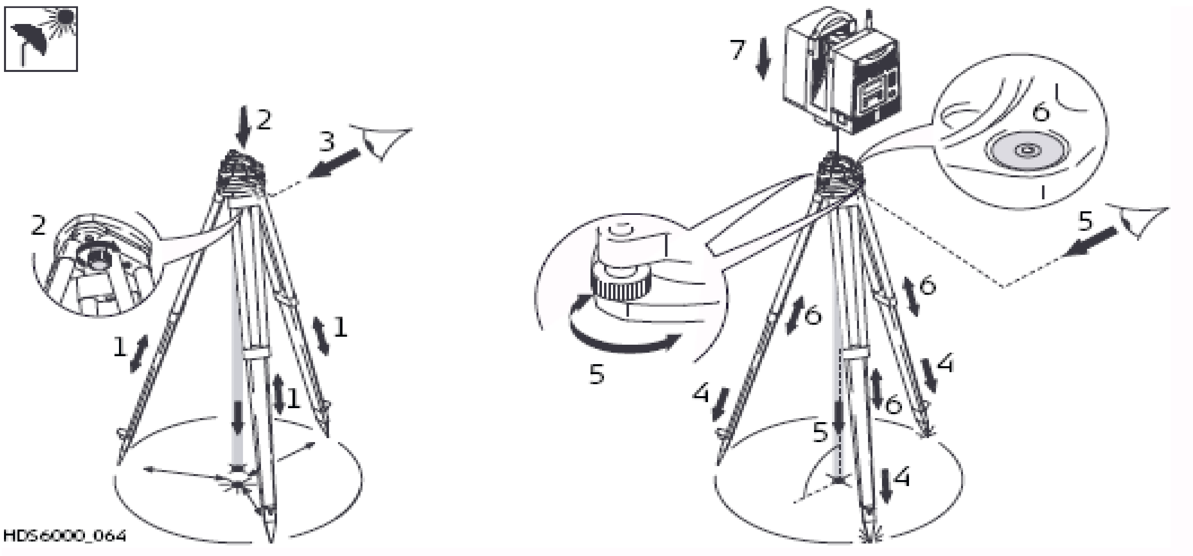


Fig 16: Parking of a laser scanner

3.2.3. Connecting the scanner

Before turning on the scanner, it is common that it must be connected to a laptop computer that can receive and store all the points to take the scanner and control their properties. The energy can be supplied by batteries, a generator or directly from the mains.

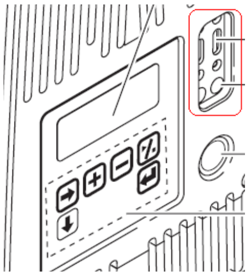


Fig 17: Complete control integrated into the Leica HDS6000 scanner

These are the steps to connect a scanner to a computer:

- Connect the scanner to the computer using the appropriate cable (standard network cable for old scanners or FireWire cable for newer).
- Connect the battery to the scanner.
- Remove the lens cap scanner and unlock the scanner (most panoramic scanners have a key lock to protect movements while being transported).
- Turn on the scanner and wait for it to warm.
- Open laptop program.
- Establish the connection between the computer and the scanner (via IP address, cable USB, wireless connection ...).
- Open the scanner control program and initialize the connection.

Art scanners are fully integrated, that is, combine a controller, data storage and battery in one piece.

3.2.4. Scanner Settings

When the scanner control program has already established connection to the scanner, you specify the parameters to be used in the scanning process.

a) Definition of the scan area

Although most current scanners can scan 360 degrees completely (Figure 35), this is not always necessary. Therefore, we need to define the scan area. To do this, there are several options.

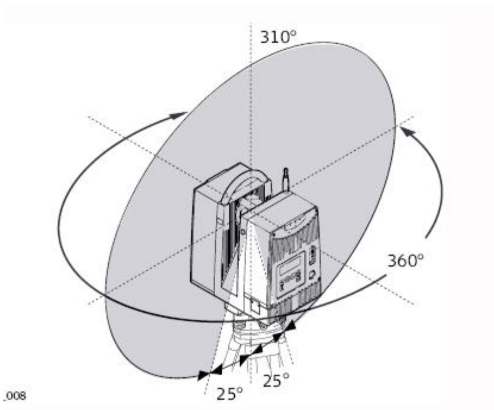


Fig 18: Example of sight Leica HDS6000 a scanner (from [27])

Some scanners have a control panel minimized in the same scanner that can define the area to be scanned. This form is very rough, but very fast.

Generally, the scan area is defined by controlling the scanner in the program.

With this method, first an image of the scene is captured and then select the image area to be scanned (Figure 36). Today, scanners or even carry cameras integrated video showing the user what is being scanned.

b) Resolution

The key issue when a scanner is used, is to choose the correct resolution. The resolution is defined as the distance between two points measured consecutively, and with this way determine the density of the cloud points. How much higher is the resolution, you will need to scan more points and, therefore, will take longer. Besides the time, the size of data stored increases.

The Scanned points at a greater distance will have a lower resolution, while the closest points will have a higher resolution.

English Heritage, an institution of the United Kingdom with considerable experience in the management of historic environments, created a table that helps determine the appropriate resolution for a project:

feature size	*example feature*	*point density required to give 66% probability that the feature will be visible*	*point density required to give a 95% probability that the feature will be visible*
10000mm	large earth work	3500mm	500mm
1000mm	small earth work/ditch	350mm	50mm
100mm	large stone masonry	35mm	5mm
10mm	flint galleting/large tool marks	3.5mm	0.5mm
1mm	Weathered masonry	0.35mm	0.05mm

c) initial filtering

There are different options: filtering by distance, by the value of the reflectivity, or a combination of both. These primary filters can be used to ensure that data are within the range of distances limit accuracy of the scanner or to remove low reflectivity points for surely will not have enough precision.

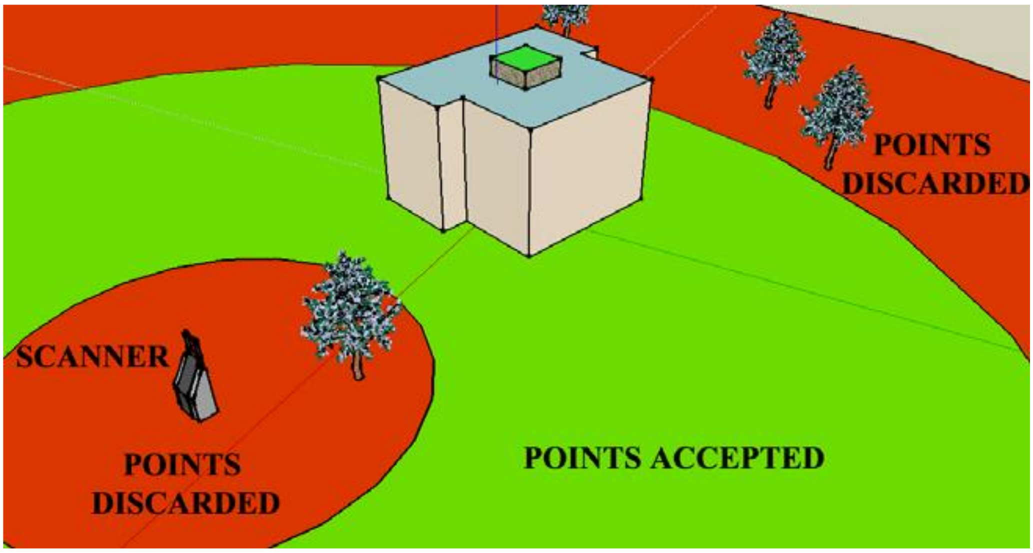


Fig 19: Initial filtering from the distance

3.3. Data collection

3.3.1. Scanning an object / building

Once you have determined the field of vision and has set the most appropriate resolution, you can start scanning. The process is fully automatic escanedo. After pressing the control button on the scanner control program or directly control the scanner, the scanner moves to the starting point and start taking points. These points are stored on the laptop or the internal memory of the scanner. When laptop is connected to the scanner, the points are displayed directly in three dimensions on the screen and give a view of the area being scanned. After scanning, it is good to check if there were by unforeseen obstructions that cause hidden areas in the data.

Depending on the selected resolution and the scanned area, the scanning process can last from 5 to 120 minutes or more. During this time it is appropriate to take notes of the lift or make a sketch of the environment, if they were not made in the planning phase. The sketches and notes uprising should show and describe the scanned objects, the positions of the numbered targets and parking scanner and specific external conditions that may influence the scanning and established settings.

3.3.2. Scanning the targets / benchmarks

When artificial or natural points of reference are used to record the point clouds these points should be labeled and measured very accurately.

Due to the limited speed scanners based on flight time, scanning is performed in two phases. First, the object is scanned with a suitable resolution for the resolution requested in the final results. In a second phase, the targets higher resolution are scanned for greater accuracy in determining its center. However, in outdoor sites it is better than the targets are first scanned and then the object to prevent any movement of targets.

After completing the overall scanning (first phase), many control programs have tools to automatically detect the targets. How are you targets are made of a highly reflective material, its reflectivity value is much higher than around them. However, how are you automatic tools often give erroneous results, it is advisable that always the results are verified and we make sure that no target is not left to take Once we know the approximate positions of the targets, are scanned with very high resolution (second phase), the scanner control program can automatically adjust a specific form of the target to the target and determine the exact center.

3.4. Data preparation

Back at the office, the data are analyzed and compared with field sketches and notes. It is advisable to start working with a copy of the original scanned and retain the original for backup. Different types of scanners store the point cloud in different ways. In Chapter 4 more about the different types of point cloud files and their advantages and disadvantages are given. In storage tasks it is important that the file format is easily accessible and recognizable. If you can access it directly, without decoding then you can convert to any other format readable with a suitable program. The file format should also contain the data in the most rudimentary form, instead of using the most preferred format for reprocessing. The most common format at this time (2008) is the format * .xyzrgb.
You should always add metadata backups, along with sketches and field notes as well as all data collected in the preparation phase.

Before processing point clouds, scanned affected by conditions extreme environmental or erroneous scans caused by human error are removed from the data set. Clouds that are not removed should be prioritized according to the "best views". The order of priority is set from sketches and field notes.

In some cases, you also need clean point clouds before recording. When the targets are placed far from the scanner or when conditions environmental bad, scanned at high resolution of targets can be filled noise. This noise should be removed before making the record because, if otherwise affect the accuracy of registration.

3.5. Registration and georeferencing

In most cases, the scanned object is too large to be scanned from one single position. Then, several parking scanner (Fig.41) are needed. Each parking is defined in the coordinate system of the scanner. Parking to align different scanner, you need to know the exact location and orientation of the scanner in a local or global system external coordinates.

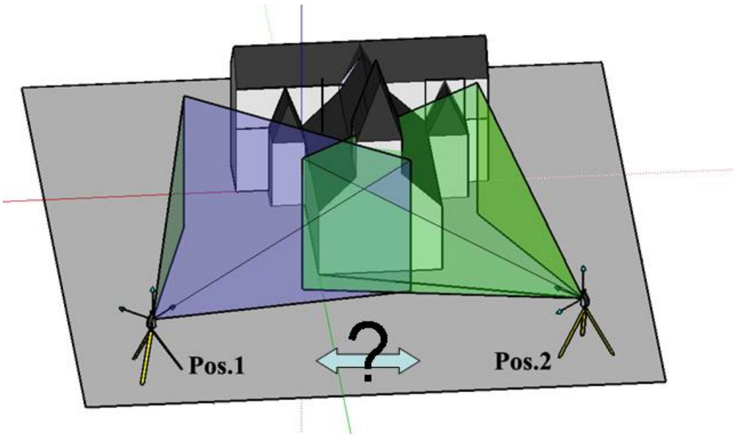


Figure 20: Registration between two parking scanner

Directly linked to the alignment, or registration, georeferencing of the entire data set is. Georeferencing means, in addition to aligning point clouds, geo-reference data set to a fixed coordinate system. The following explains the different possibilities to carry out the registration and georeferencing.
This tutorial categorizes the registration techniques in recording techniques or direct and indirect georeferencing

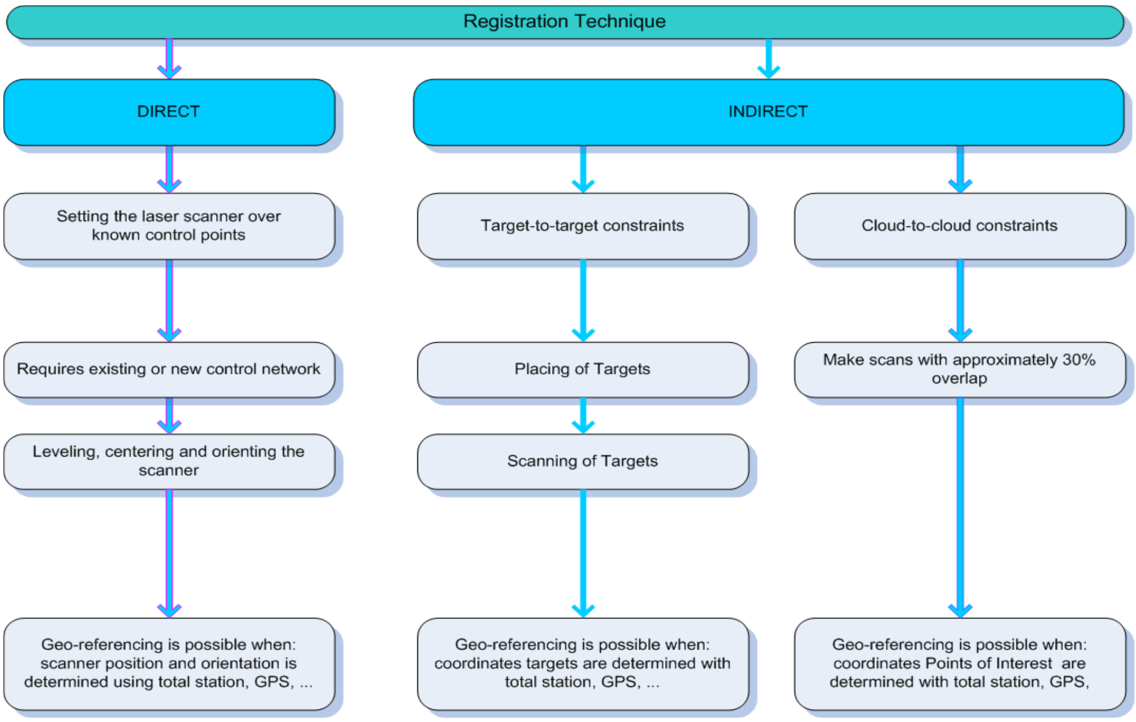


Figure 21: Registration Techniques

3.5.1. Indirect registration and georeferencing

Indirect registration involves the use of (artificial or natural) targets on stage to align the point clouds. If you need georeferencing to be measured benchmarks by surveying techniques and transform to a known coordinate system.
To carry out the indirect register at least three reference points present is needed in the two clouds of points to register. However, it is always better to have more than three points, because this way the errors can be minimized using a least squares adjustment.

3.5.1.1. target registration target

Places with easy access no problems when placing the targets. Artificial targets can be a variety of ways. There are special targets that you supply companies themselves laser scanner made of highly reflective material. However, the printed paper targets can also be used. When no artificial targets available, improvising taking objects whose surface can be adjusted to an ideal geometric surface. For example, they can be used pieces of cylindrical tube. Processing programs let you adjust scanner cylinder to the point cloud of the object to determine its central axis with high accuracy. If the cylinders are placed in both vertical and horizontal directions, they can be used to align different point clouds.

In inaccessible areas, for example in high altitudes, you can use natural entities. These entities or natural targets are points of interest in the structure itself scanning that can be identified with high accuracy, for example edges of windows or cornices. The registration result with natural white is made worse than artificial targets. The reason is twofold:

- Common entities on two different points clouds are not composed of identical points, which are, essentially, circles of several millimeters in diameter, due to the divergence of the laser beam.
- The identification of common entities is rather subjective, especially in scanned steep

Register cloud to cloud

Another way to register two point clouds is using the overlap between the point clouds.
If two point clouds have enough overlap (usually between 30 and 40%), you can use the technique called ICP (Iterative Closest Point) to align both datasets. This technique requires the user to check at least three pairs of corresponding points in the point clouds. As these three pairs will never be exactly the same points, the ICP algorithm iteratively checks the distances between all points of the clouds and estimates the transformation to align both sets so that the error is minimized.

The rules for the configurations of the targets mentioned in the preceding paragraph are applicable to the configuration of the points in the cloud to cloud registration.

This recording technique should be used with caution. When very long linear structures in which several parking lots, small errors in the registration of each consecutive pair of point clouds can spread and produce large global errors are needed are scanned.

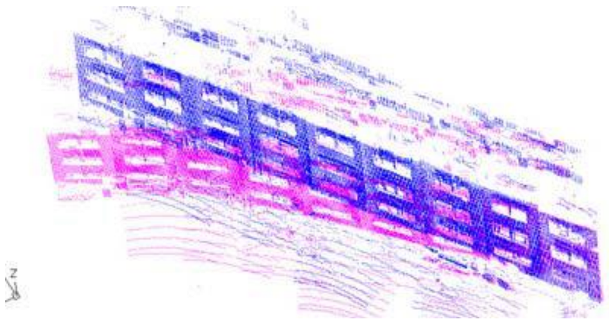


Fig.22 error propagation due to cloud to cloud registration of multiple point clouds of the facade

Registration surface to surface

In 2006, A. Gruen published a new technique to align cloud by adjusting geometric surfaces of two scans. His algorithm estimates the Euclidean distance between surfaces fragments by least squares and attempts to minimize these distances iteratively, as in the ICP algorithm. This method offers high flexibility for any type of correspondence problem 3D surfaces as well as
statistical tools for analyzing the quality of the final result.

Registration surface to surface is especially useful when some clouds contain substantial noise. In this case, it is better to clean clouds triangularlas first and separately so that each is processed with the most appropriate settings. When all the clouds have become surfaces, you can use the recording surface to surface to align different scans.

3.5.2. Registration and direct georeferencing

Direct registration means that the position and orientation of the scanner are calculated directly. This can be done in two ways. An example is the case of a laser scanner with some functions total station, where the scanner can be parked directly over a known point using a laser plummet. The orientation can be determined by scanning a single point of reference in the following location of the scanner. These scanners also have a dual-axis compensator that within limits levels. This leveling scanner involves a third restriction on the orientation of the scanner.
Sometimes, a special reflector is fixed to the top of the vertical rotation axis of the scanner. The exact position of the reflector with respect to the center of the laser

beam can be determined after a calibration process. Then the reflector can be measured with a total station as if it were part of a polygon. Another way to determine the location of the scanner is placing a GPS receiver on the scanner.
This technique reduces the number of targets to consider and therefore avoids large requirements as to the configuration thereof. Furthermore, it does not need to point clouds overlap. Given all these considerations, this technique is usually faster than the indirect register
When you need georeferencing, the position of the reflector can be transformed to unsistem known coordinates using surveying techniques.

3.6. Processing 3D point clouds
Processing a point cloud refers to the transformation of raw cloud of points recorded in the final result. The end result may take several formats: cleaned cloud points, standard 2D (drawings, elevations, cross sections ...) drawings, 3D models and animations fully textured for navigation.
In the figure below (Fig. 44), a vision of the different stages of processing laser scanning and degree of automation is shown.

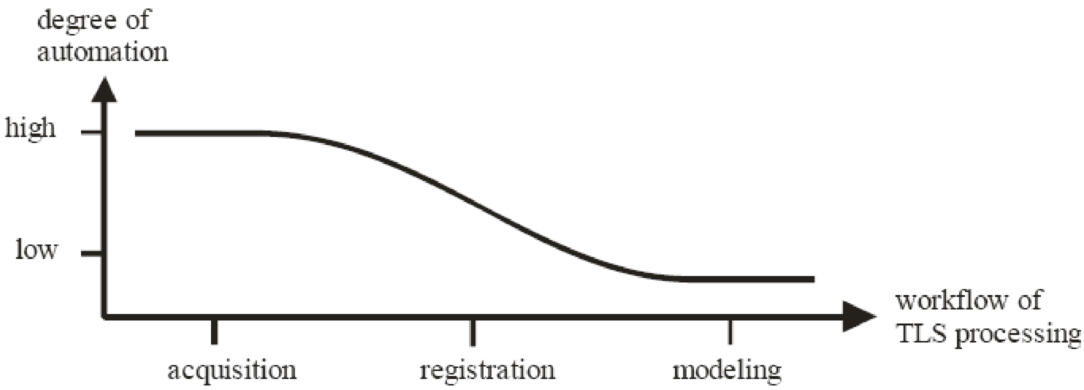


Fig 22: Automation of processing steps of a terrestrial laser scanning

Generally, the processing of a 3D point cloud, can be divided into two categories. The final results can be extracted directly from the point cloud without further processing, or first creating a 3D model of the surface from the point cloud and extracting the results of this model. Which method is chosen will depend on the results orders. For example, when only a limited number of cross-sections are required, it is better to remove them directly from the point cloud. However, when a larger number of sections (over 50) is required, the second method is more efficient because there are automatic to generate multiple sections from a triangulated model tools. In addition, the surface model adds more value and understanding that only the cloud of points recorded.

3.6.1. Representations point clouds

The result of a catch of a scanner is a lot of points in space, each having a X, Y, Z (Fig. 45) and normally a value of reflectivity. Some scanners provide even color information as RGB (red, green and blue).

The point cloud can be represented by drawing all points on the screen, but this leads to a chaotic impression and the user may have difficulty recognizing structures in the cloud. When each point is displayed with its value of reflectivity or color, the set of the entire structure is better understood.

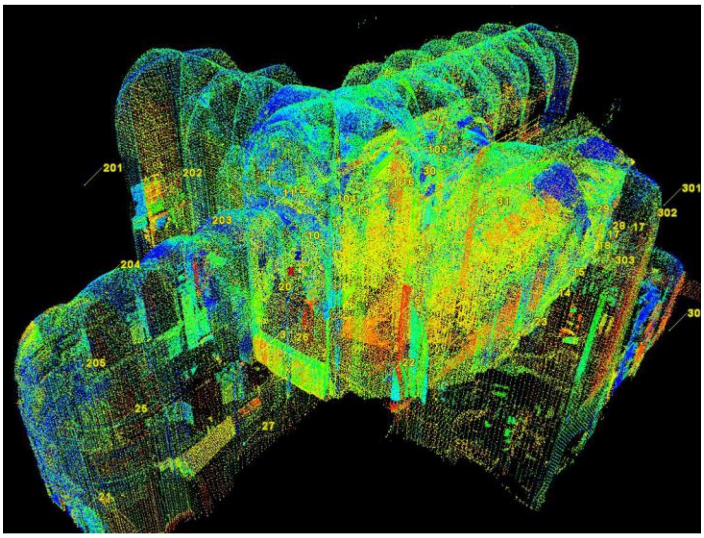


Fig 23: Image of an unorganized point cloud

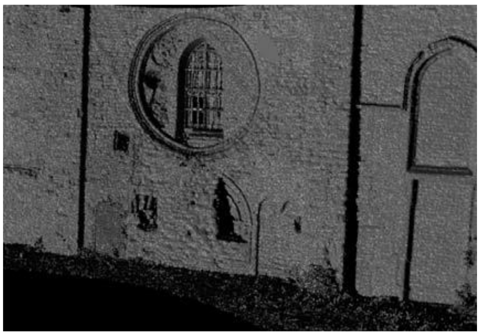
Like most scanners take a scene in rows and columns, a way to represent a point cloud in a very simple way it is with a map of depths. A depth map is a matrix-shaped structure (2D) in which each pixel represents the distance from the scanner 3D point as a gray value. Because this type of representation incorporates information from the environment of each point, it is useful in processing algorithms point cloud and cloud organized cone points known.

Fig 24: Map of depths

Using complex algorithms modeling (triangulation), neighboring points can be connected to form surfaces. This provides a closer representation of reality because the surface structures or patterns are not transparent and therefore the points left behind other can not be seen. Calculating the normal direction of the surface, you can use artificial shadows to emphasize details of the surface.

As the generation of models, especially from point clouds not organized, is complex and can take considerable time, there have been attempts to find alternatives to achieve an approximate representation of the cloud only to view and analyze it faster. As a result, the idea of point splatting, which generate "surfels" ("Surface Elements), small surface elements for each point cloud created from raw laser scanner data (Fig. 47) was launched.

Each surfel is represented by a small primitive surface shape (circle, ellipse ...) 3D inherits the normal of the surface with its neighbors. This results in a representation of the very fast surface.



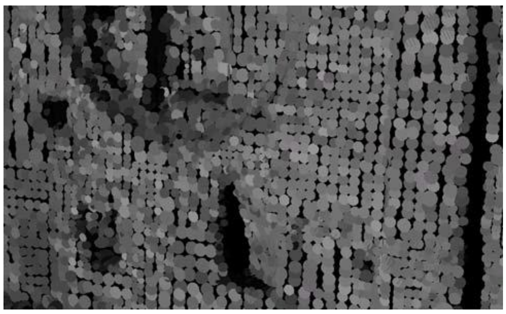


Fig 24: Result of point splatting (left), approach to it (right)

3.6.2. Improved data

Noise Filtering

A first step in the process of meshing is the elimination of noise data point cloud. If the noise is introduced because of the wind, bad reflection surface, etc. (See section 2.6), the model will contain triangles connecting the points with noise at the correct points. This produces a full mesh of peaks. It is therefore important to remove this noise in the first step.

Often, the operator can easily identify some scanned parts but are not required in the final results. It is therefore advisable that the operator carried out a first analysis of the point cloud and hand remove all unnecessary points.

Automatic algorithms that eliminate noise is mainly based on two beginning. The first is the fact that the points that have few or no spots around, are considered noise. They are probably caused by people and other obstacles ahead that move the scanner while the scanner is operating. These points are easily identified using a limited number of adjustment parameters and therefore removed from the point cloud.

Another principle of elimination is slightly move the points to achieve optimum surface smoothness. These algorithms attempt to adjust planes cloud points locally. When the focus is adjusted far plane, it moves toward the plane so that a better consistency proportions their neighbors.

There are also other noise filters, some specialized according to the type of scanner, which eliminate systematic errors points. Of course, care must be taken when noisy points is eliminated as entities may be lost when soften excessively or when too many points are removed

Resampling

As mentioned above, when a mesh is created, the number of triangles is more than twice the number of points. A model of a point cloud of a scanner phase can have more than 20 million triangles easily. This amount makes it difficult to work with standard programs. Generally, you need to reduce the number of triangles before creating the model. This point reduction can be done in two ways:

The easiest way to reduce the number of points is to eliminate a point that is very close to other points. The points can be removed while all the scanned area is maintained. However, this technique can eliminate points in areas containing important elements and therefore valuable information is removed.

Another way to remove points is given the curvature of the surface to determine if part of the surface is smooth or very curve. This resampling technique works intelligently, keeping the important points in areas with high curvature and eliminating points in areas that can be represented with fewer. With this technique a better reduction of original point cloud is achieved without losing valuable items.

3.7. Presentation of the building object of the fieldwork.

The building that we are going to scan with the technology before mentioned, is situated in the street Bem No. 27, Dunakeszi 2120.Hungary

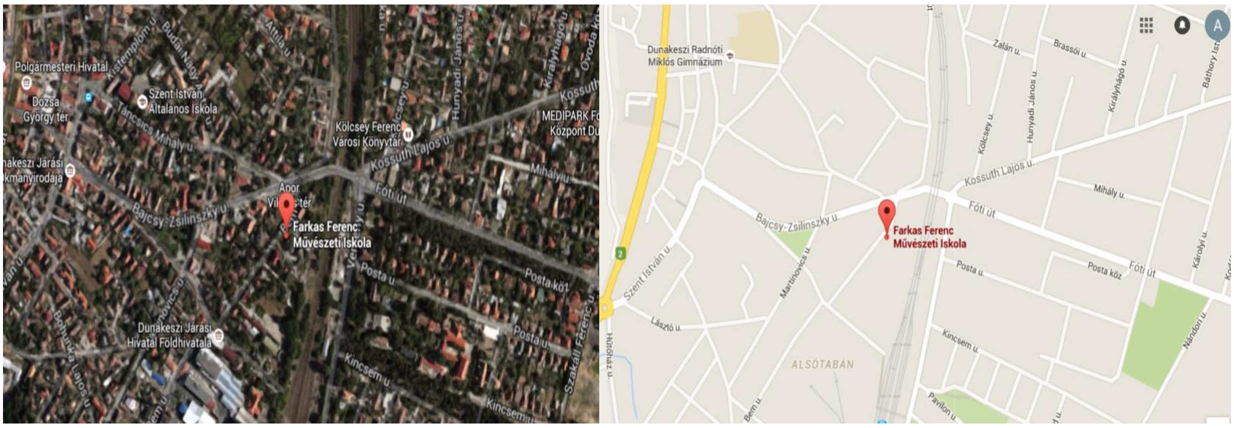


Fig 25: ***Aerial plant***

Fig 26: ***School Building to scann***

3.8. Point cloud resulting. Treatment of the information.

Once we have the cloud of points, we proceed to export the Autodesk program called ReCap

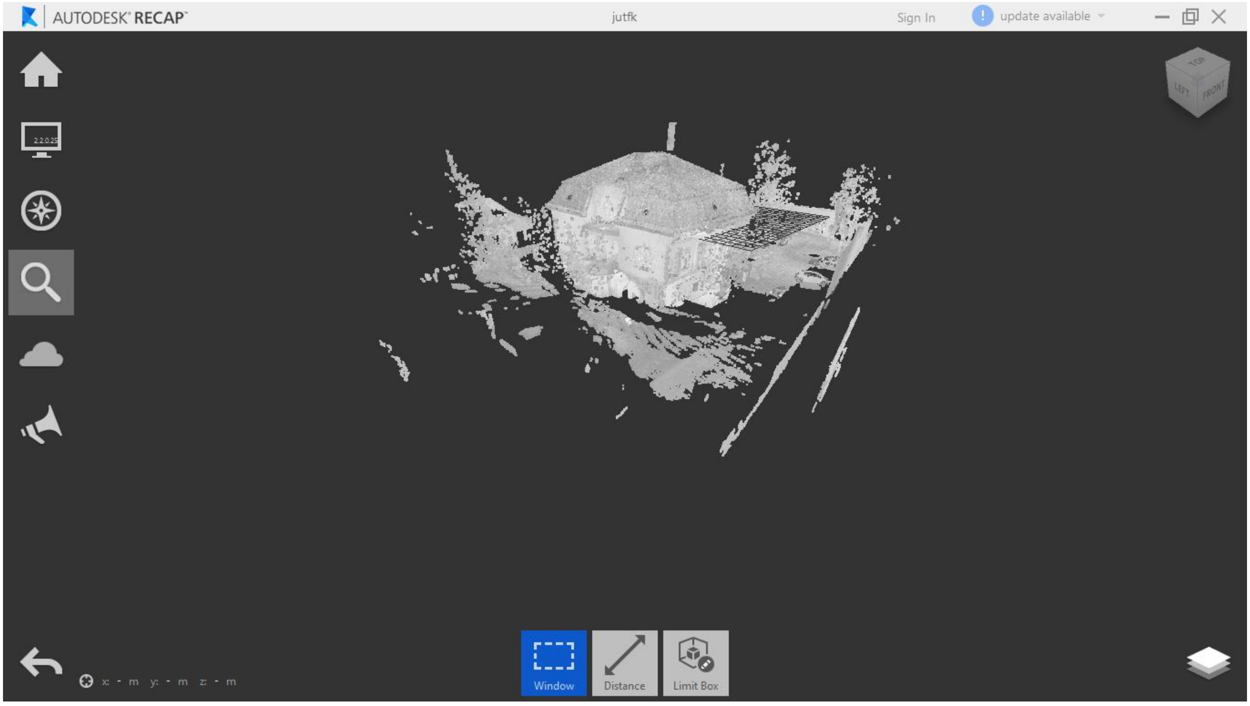


Fig 27

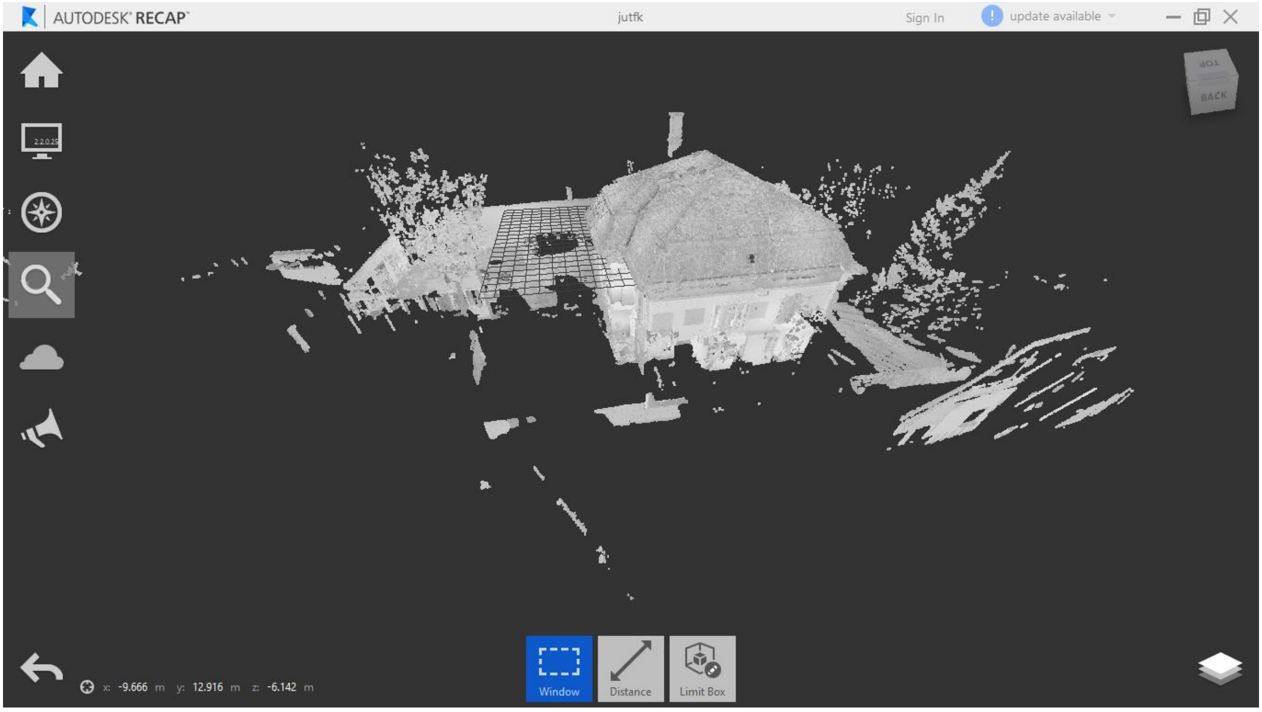


Fig 28

In the cloud of scanned points, there are many things that are part of the environment that does not interest us, like trees, etc and they take a lot of memory in our arhivo. Therefore, we will edit through Recap, so that only left us the house as element modeling in Revit

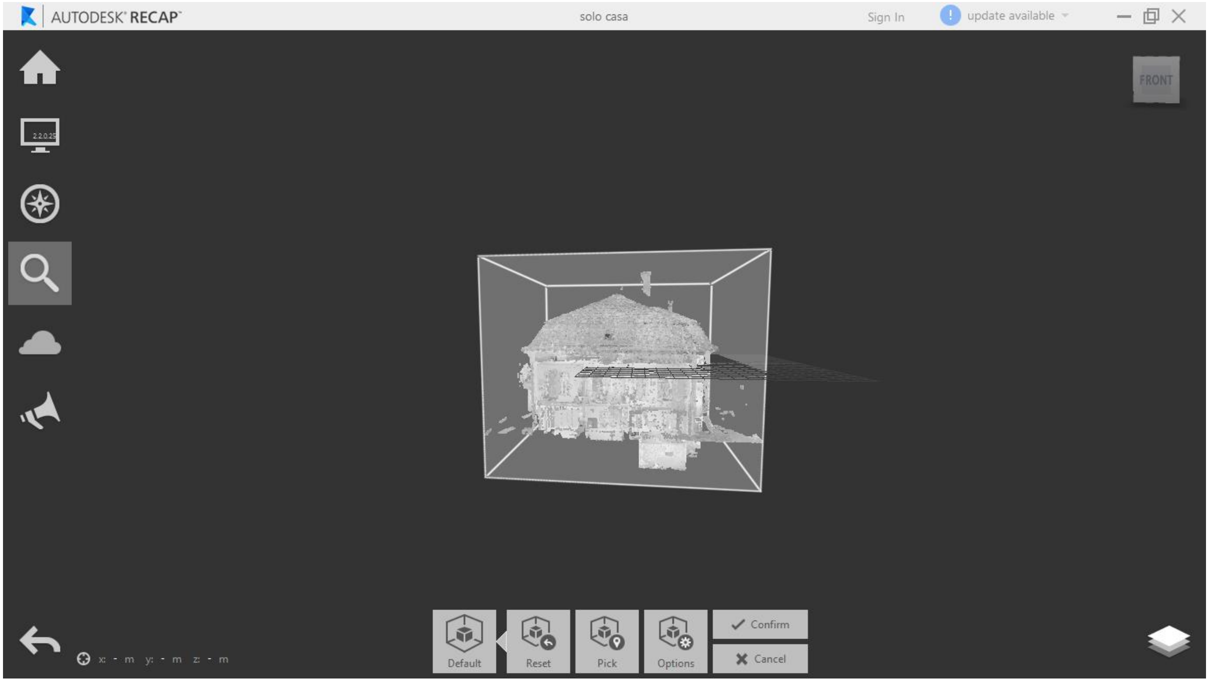


Fig 29

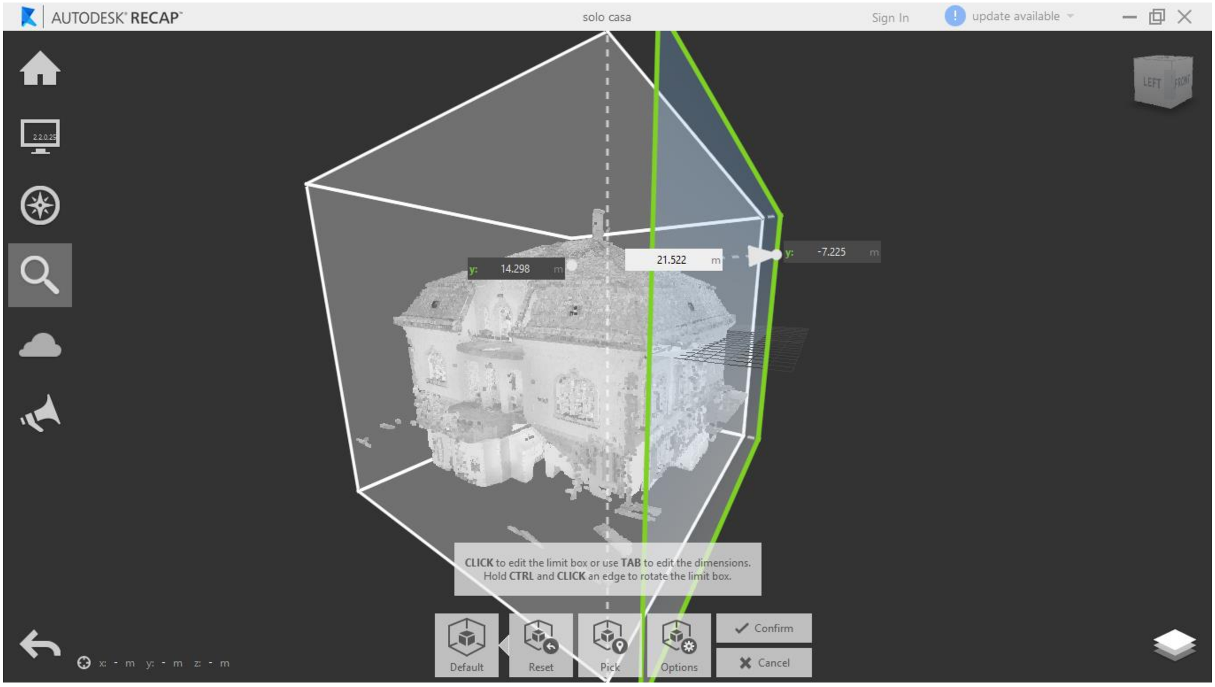


Fig 30

This is the result obtained after editing the point cloud

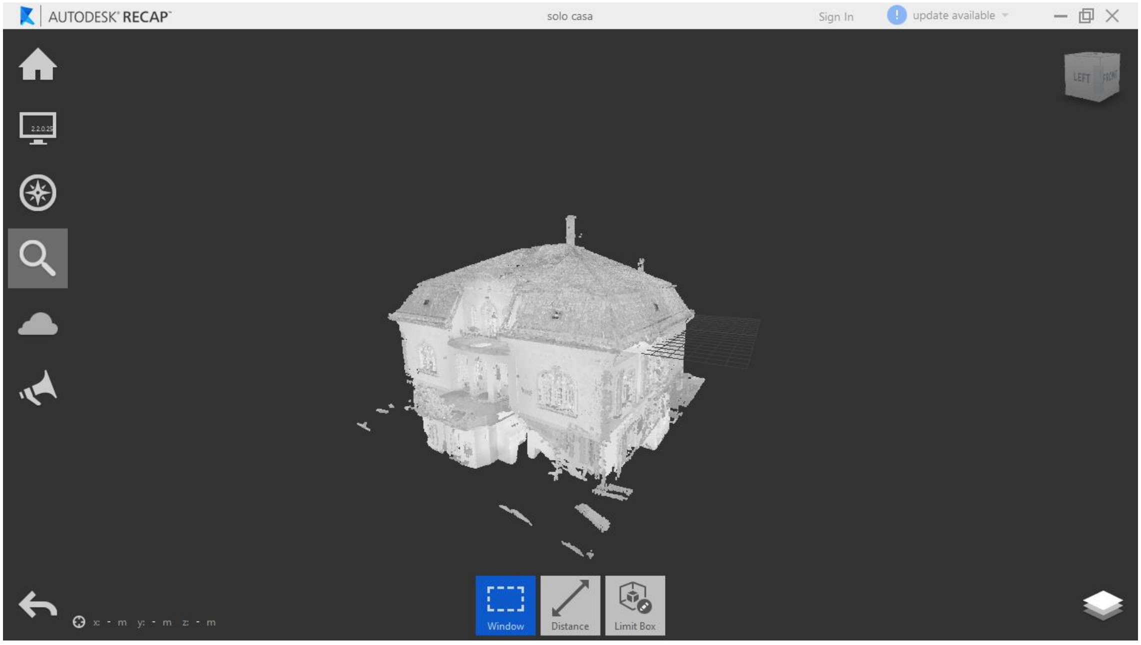


Fig 31

3.9. 3D Modeling BIM resulting from making digital data.

Once the point cloud have prepared in Recap (see fig 31) we export it to Revit, where we start to model the building

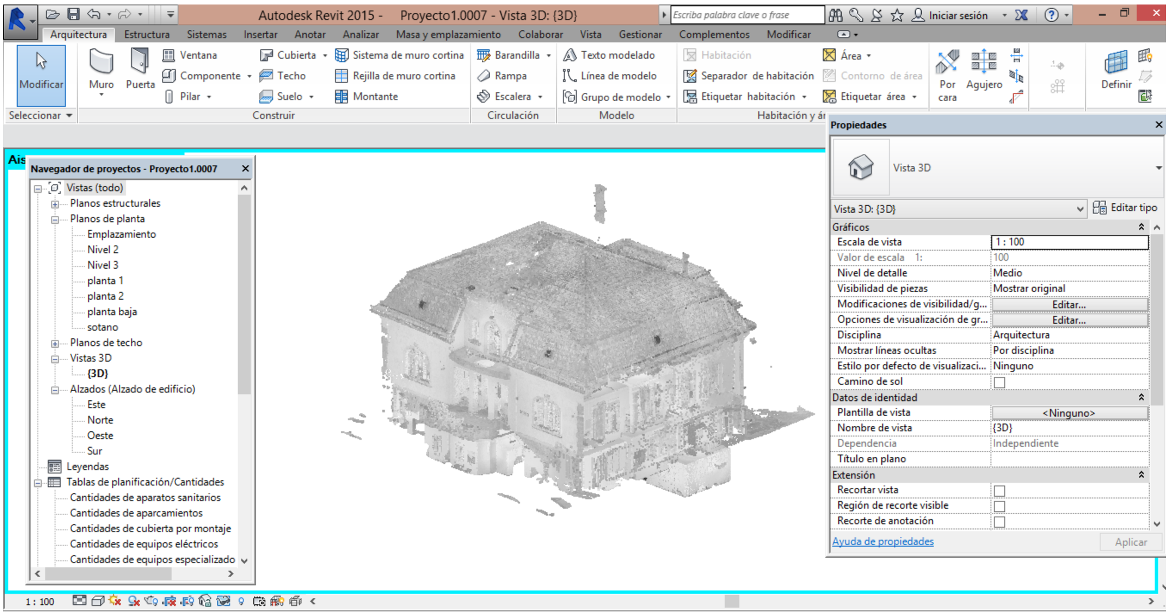


Fig 32 Point cloud in Revit

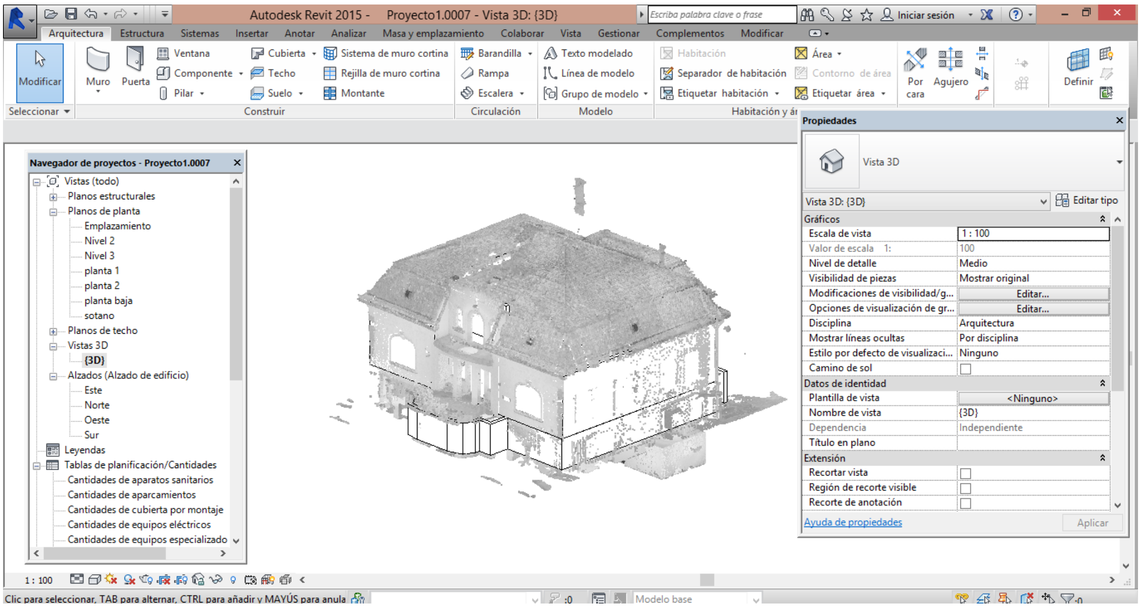


Fig 33 Start to model the building

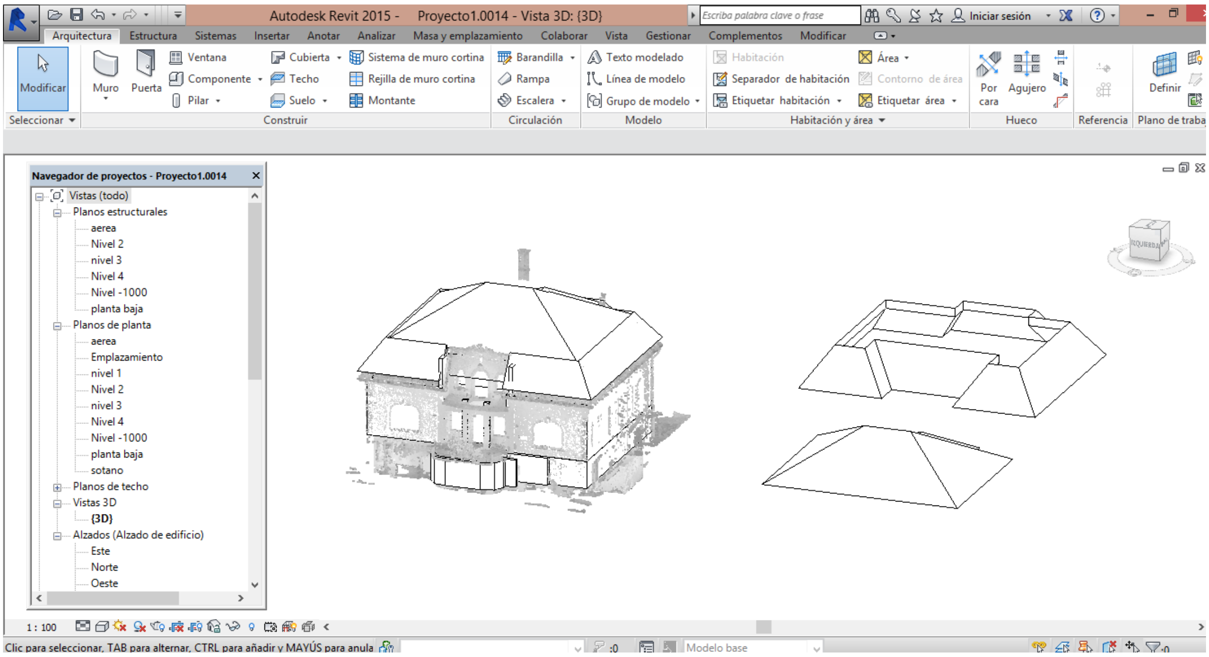


Fig 34: One of the most difficult parts of the building to model, it was **the double pendent of the roof**

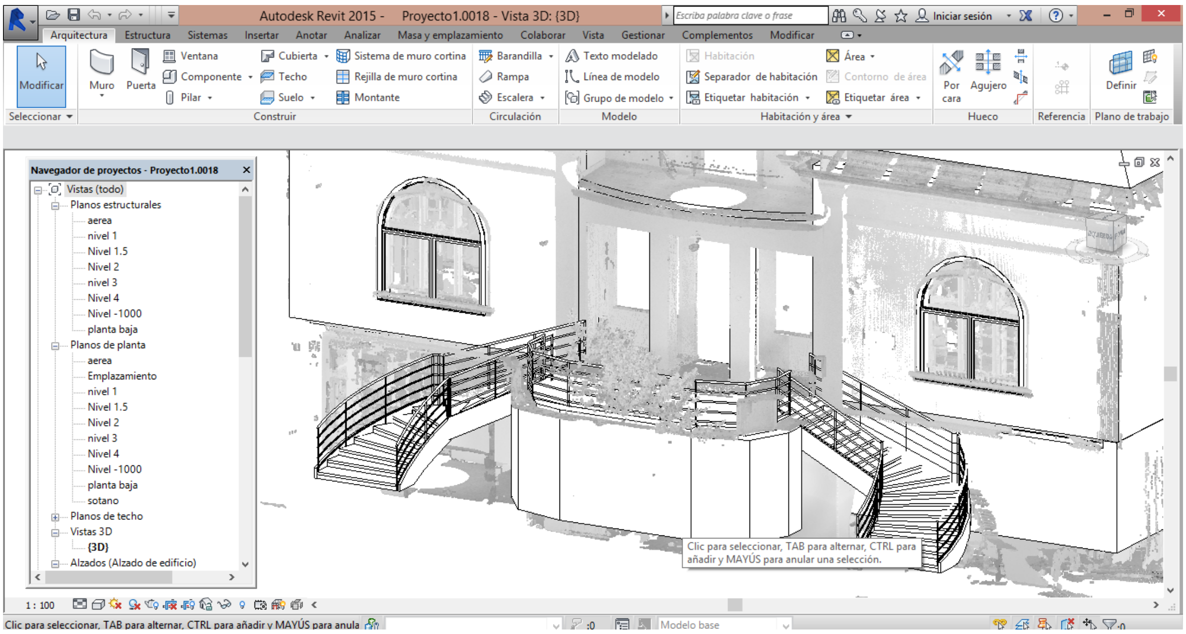


Fig 35: Other really difficult part it was the **stairs** of the front of the house

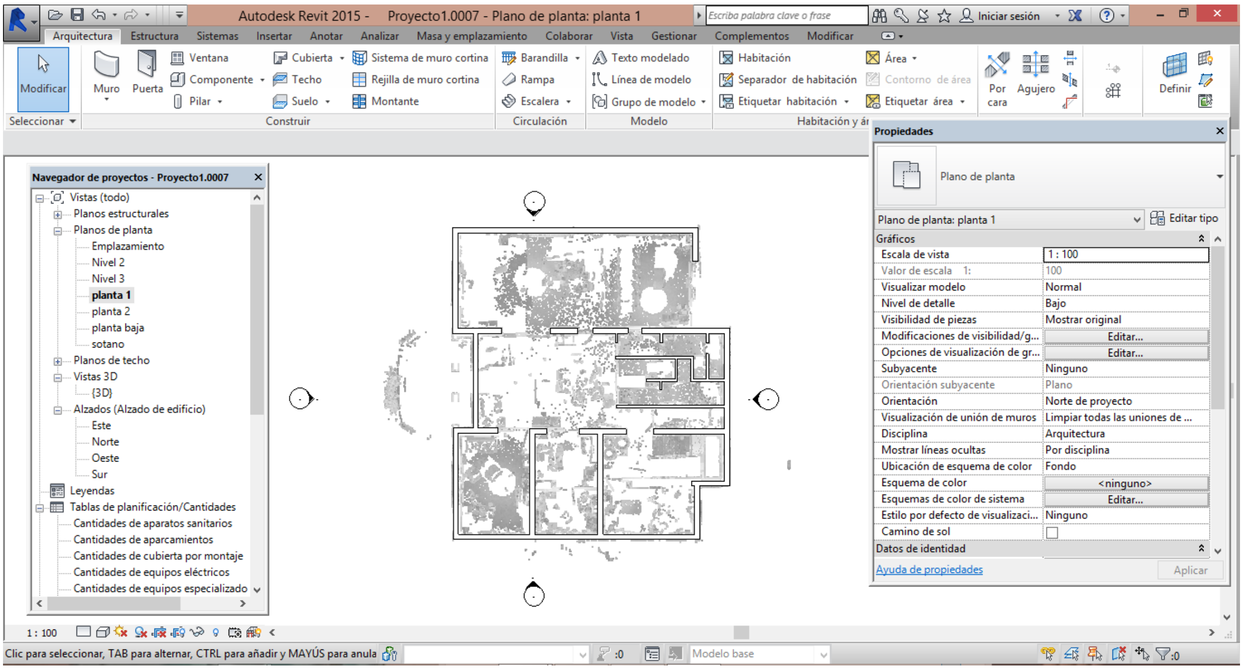


Fig 36: In this picture we can see how to start to do the differents walls of the building

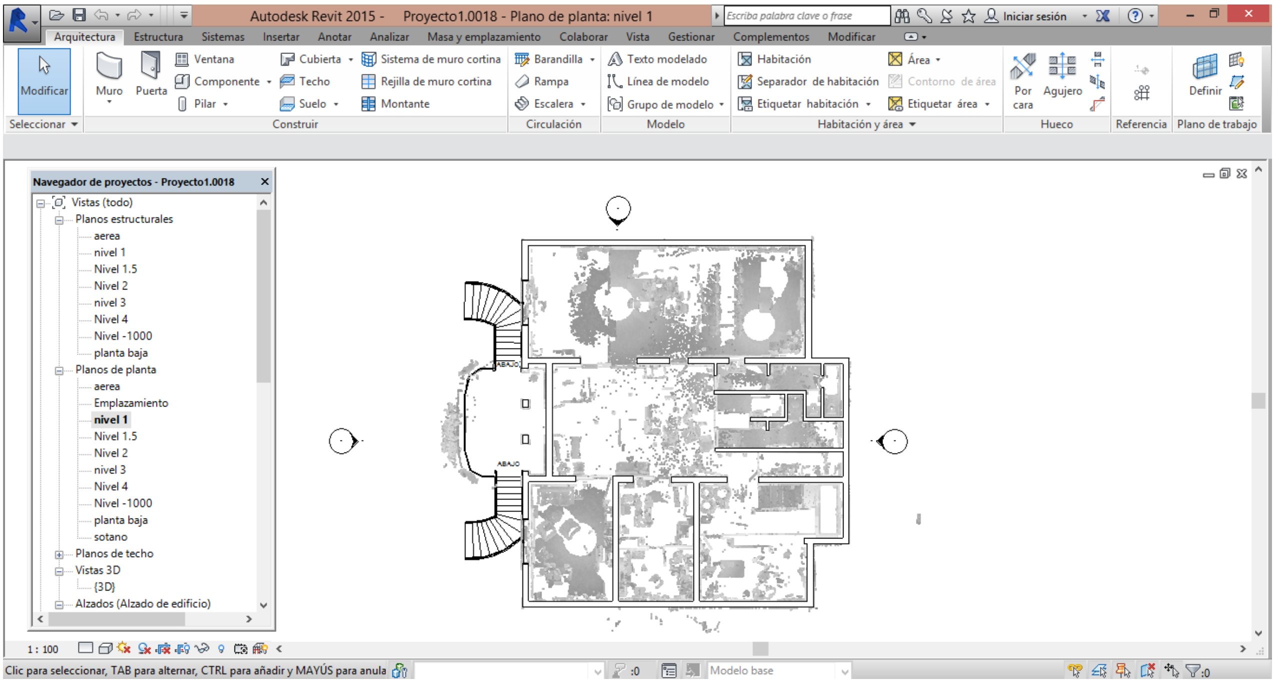


Fig 36

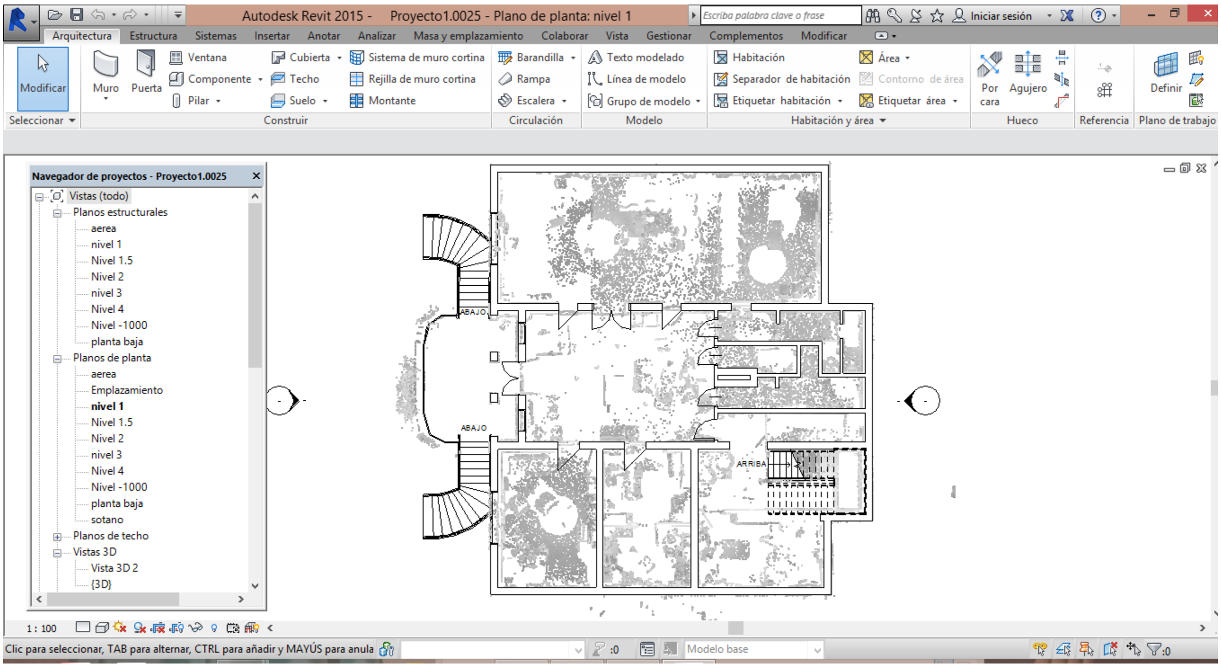


Fig 37: After, put the interior furnishings

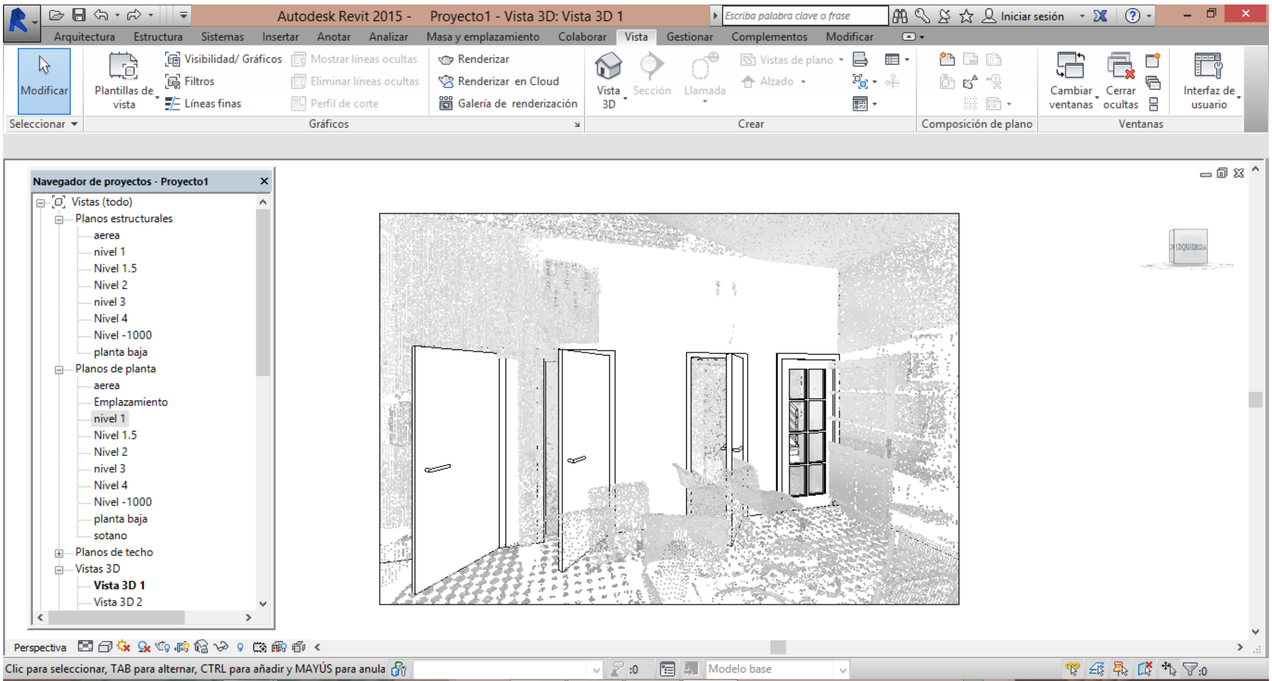


Fig 38: Interior View (with the point cloud)

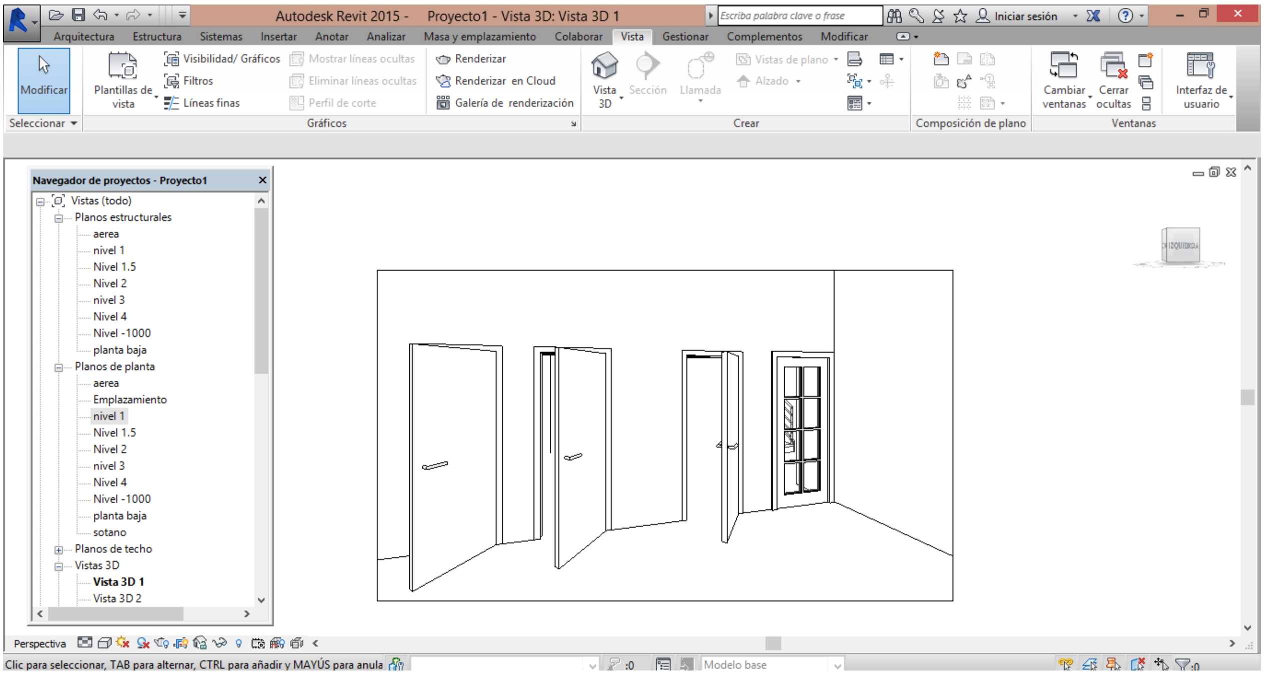


Fig 39: Interior view (without Point Cloud)

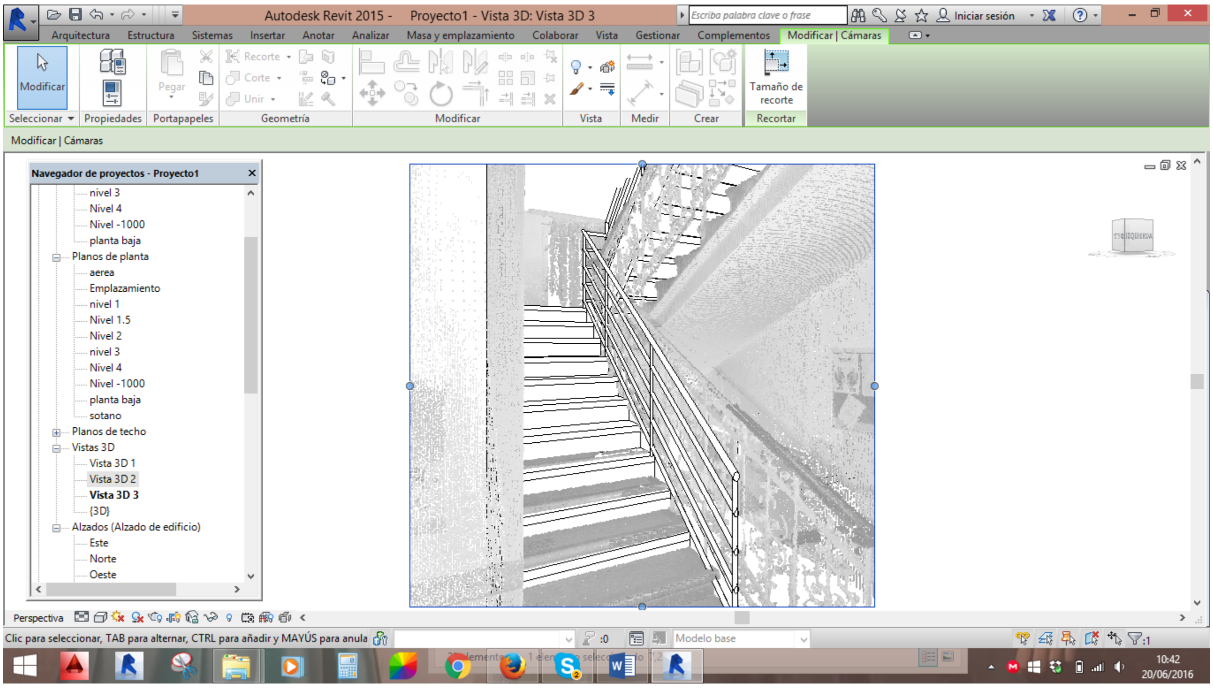


Fig 40: Interior view of the stairs (with Point cloud)

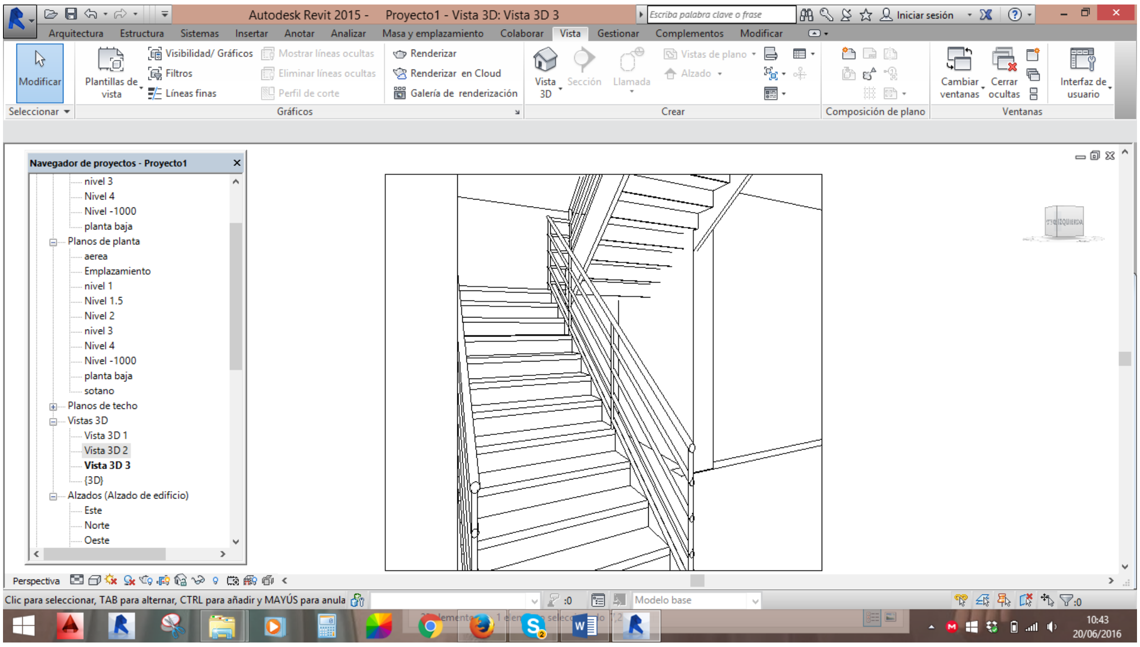


Fig 41: Interior view of the stairs (without Point cloud)

To see and make the details on Revit, i had the help of one program online (Scene webshare) , where i could see in 3D all the point cloud of each part of the house. Like we can see on the picture, i could see the position of the view in each moment, with a very big resolution to make me understand what should i do in each moment

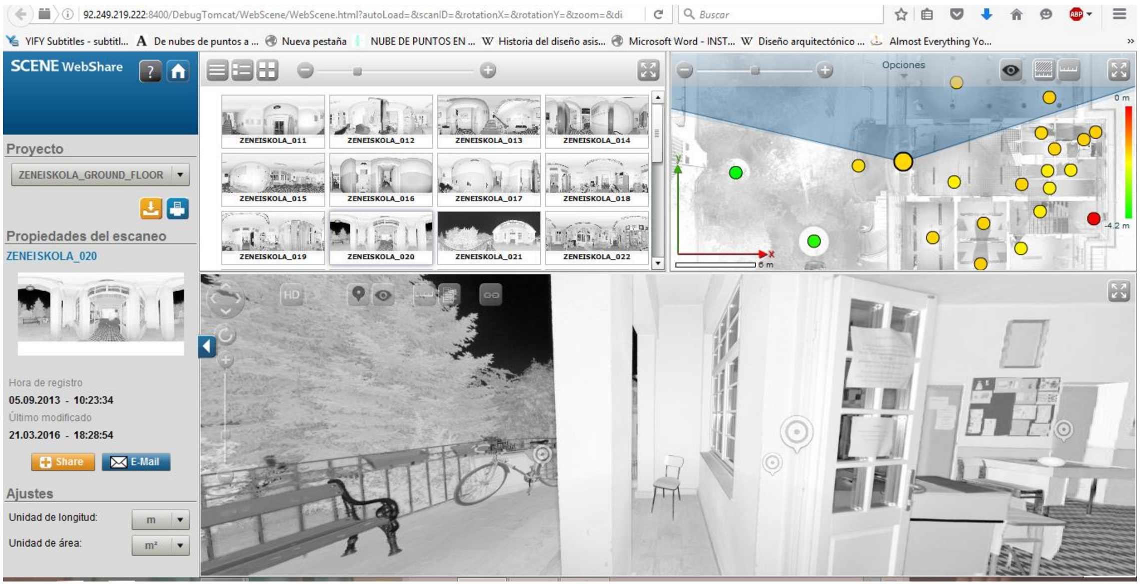


Fig 42

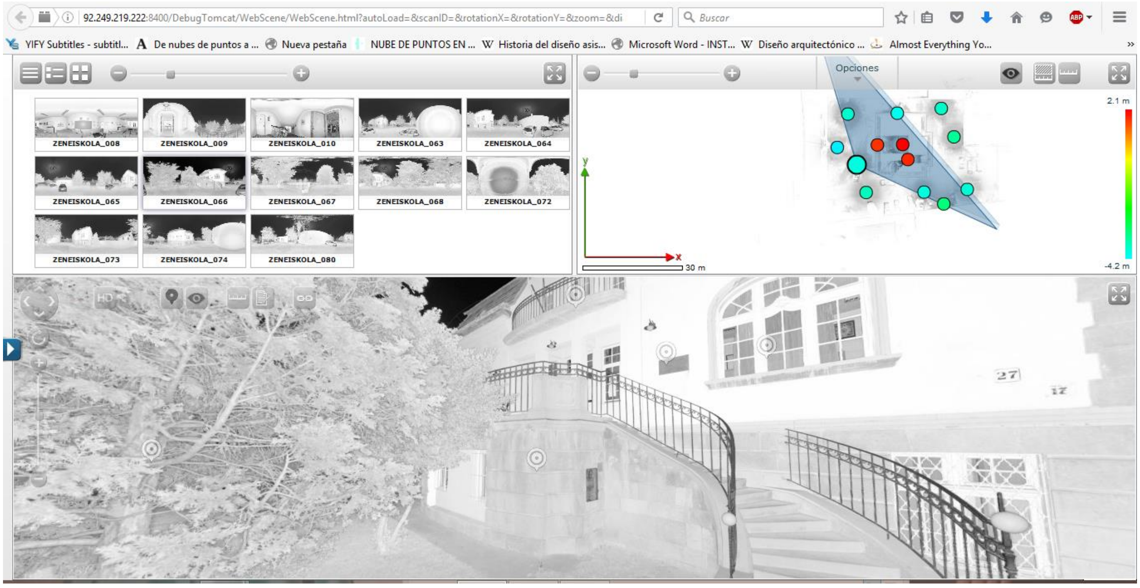


Fig 43

Results Obtained

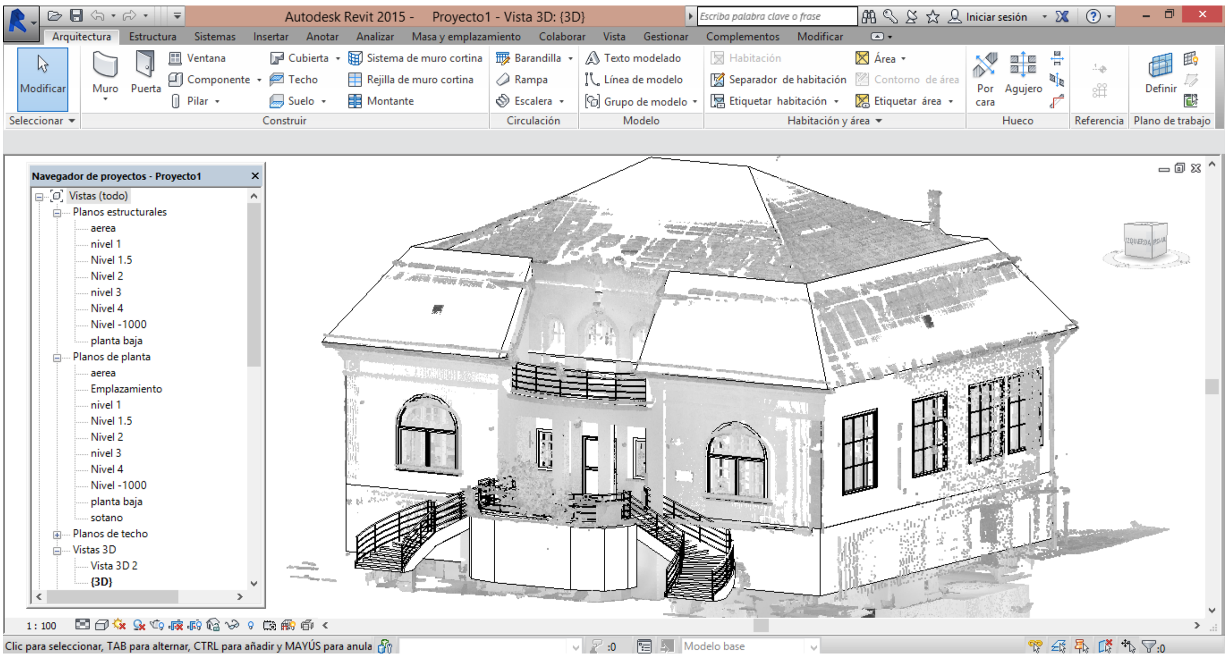


Fig 44: To finish, we have the building modelled that include all the information data what we have explained during the project. With this model with all the information, we can work for the future if we want do some change on the building

4. CONCLUSSIONS

After studying that is, how it works, and how to apply it to functions within the field of architecture, we can talk about a very useful technology, with many advantages dela we can benefit greatly.

The advantages of the 3D laser scanner on other measurement techniques are:

- Fast data collection
- Measurement accuracy
- Safety in hazardous or inaccessible locations
- Fewer technician visits
- Greater range of working hours to not be affected by the brightness

So finally, thanks to this technology, we will gain time and precision because of its speed. Also is very intuitive for workers who have to carry out the informatic to real life work. That means that we will have a better job on the ground in less time and costing less money

We have seen the application of the laser scanner in the BIM, really interesting in the case to repair or change some partsof the building that we have scanned.

For the future, it would be good that this technology would be applicated and used in Spain and in the rest countries of Europe

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