

# CLASSIFICATION AND INFORMATION STRUCTURE OF THE TERRESTRIAL LASER SCANNER

*Methodology for analyzing the registered data of Vila Vella, historic center of Tossa de Mar.*

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## Abstract

This paper presents a methodology for an architectural survey, based on the Terrestrial Laser Scanning technology TLS, not as a simple measurement and representation work, but with the purpose understanding the projects being studied, starting from the analysis, as a process of distinction and separation of the parts of a whole, in order to know their principles or elements<sup>1</sup>. As a case study we start from the Vila Vella recording, conducted by the City's Virtual Modeling Laboratory in 2008, being taken up from the start, in relation to the registration, georeferencing, filtering and handling. Aimed at a later stage of decomposition and composition of data, in terms of floor plan and facades, using semiautomatic classification techniques, for the detection of vegetation as well as the relationship of the planes of the surfaces<sup>2</sup>, leading to reorganize the information from 3D data to 2D and 2.5D, considering information management, as well as the characteristics of the case study presented, in the development of methods for the construction and exploitation of new databases, to be exploited by the Geographic Information Systems and Remote Sensing.

## 1. INTRODUCTION

The architectural survey concept has been widely debated<sup>3</sup>, reaching regarded as an approach to architecture that analyzes (identified, selected ...) and summarizes some of its episodes by graphical operations objective, rigorous and effective in relation with the intentions or purposes in view.

This paper takes a project conducted by the Virtual City Modelling Lab (LMVC), which is composed of the record and the floor plans of Vila Vella in 2008, with the Terrestrial Laser Scanner Riegl z420i, for the special plan of the historical center of Tossa de Mar, being the

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<sup>1</sup> SEGUÍ, Javier., Escritos para una introducción al proyecto arquitectónico, Madrid, 1996, pp 90

<sup>2</sup> Fischler, M, Bolles, R., Random Sample Consensus: A Paradigm for Model Fitting with Applications to Image Analysis and Automated Cartography. Comm of the ACM, Vol 24, 1981, pp 381-395.

<sup>3</sup> GÁMIZ, Antonio, Ideas sobre análisis, dibujo y arquitectura, Universidad de Sevilla, Secretariado de Publicaciones, Sevilla, 2003, pp 130.

final of the project the point cloud with color and intensity, videos and orthogonal images of the street facade and floor plan, generated from the rendering of this cloud of points. This base is analyzed critically to allow subsequent stages of the data analysis.

And proposes a methodology to proceed to other stages of analysis of information, regarding the use of data from images, not as a process of rendering the point cloud, in which there is no control of the data to pixel level, are not taken into account the different characteristics of resolution or occlusion of scanned objects, but a process of converting data from 3D to 2D and 2.5D, methodically, starting from the classification of the information and its reorganization in Floor plan and facades, to enhance and complement the information base, with image processing techniques.

The paper is organized as follows: Section 2, description of the case study. Section 3, information management 3D TLS, highlighting registration processes, given its importance to the combination of data and images, in relation to the noise data, being an error that limits the analysis of this information in two dimensions (in contrast to processes that require only visualization). Section 4, is posed segmentation strategies, reorganizing and standardizing information, semi-automatically, seeking for data homogeneity. Finally, in Section 5, we propose the use of new databases according to their formal characteristics, differing data facades, floor, ceiling, complex elements such as vegetation and furniture.

## **2. Case study, Vila Vella**

Declared a national historic monument in 1931, is the only example of a fortified medieval town that still exists in the Catalan coast. At its peak (s. XV), the *Vila Vella* integrated eighty houses. Most of these used the rampart as the wall bottom wall. From s. XVI population began to expand outside the wall and the first buildings were constructed in the *San Roqueta* and along the royal route.

The current condition responds to several restorations, especially at the end of s. XIV and during the s. XVIII, keeping the original perimeter battlemented walls, which are distributed in four towers and three cylindrical towers topped by battlements. The towers most famous are *d'en Joanàs*, who chairs the bay, the tower of the Hours, located at the entrance of the courtyard, which is named after that was the only place where a public clock stood, and *Codolar* tower is also known as the Tower of Homage, chaired *Codolar* beach.

## **3. Registration and information management TLS**

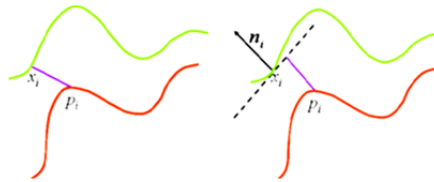
The survey developed in 2008 did not have the support of a survey instrument and did not have at that time neither GPS nor electronic level, so the vertical model was unreliable, had no connection with other database as for georeferencing and not made a check of the accuracy achieved between positions, that would continue to stage segmentation without the wrong information to find registry errors, emphasizing its complexity with the fact of being an urban uprising in which were mixed distant positions with nearby, making it difficult to visually identify the registration error due to the low resolution at large distances. So we conducted a second registration process, which begins with an understanding of the method used, and extensive experience with this type of survey, raising considerations to take into account in applying iterative methods.

### 3.1 Method of registration, Iterative Closest Point ICP

The ICP Registration is independent of the nature of the geometric data (points, curves of different degrees of the surfaces). It is based on minimizing the distance between two clouds, point by point, by successive iterations. The main disadvantages this process in its original form, is the convergence to a minimum which may be false, especially when there is a lot of noise in the data, and it takes a large number of iterations for convergence of the model.

Despite all the studies that attempt to automatically find the initial values of the ICP algorithm and its convergence speed, as with the work of Mitra in 2004<sup>4</sup> and Wang in 2008<sup>5</sup>, based on fuzzy logic, a variant is still used semiautomatic, leaving the user three corresponding points in two clouds to register. With these starting points, it is possible to calculate an initial rigid transformation and then start the iterations. However it is not always possible to find homologous points in the point clouds, thus speaks of "hotspots", if the algorithm does not find them, try to replace them with the closest points, Figure 1. Besl and McKay in 1992<sup>6</sup> studied the mathematical relationships necessary to define the closest point (belonging to a geometric series) to another known point, for example, considering that the distance between a point and a set of points defined by the minimum distance between this point and each point of the set, the point which allows the calculation of the minimum will be considered closest.

**Figure 1:** The closest point to the tangent plane to a surface at a known point



**Source:** Al Shawa 2006. Describe the process developed by Besl and McKay, 1992.

Suppose that  $R$  is the rotation matrix and  $T$  is the translation vector. To minimize the function  $f$  is described by the following equation<sup>7</sup>:

$$f(R, T) = \frac{1}{N_p} \sum_{i=1}^{N_p} \|\vec{x}_i - R\vec{p}_i - \vec{T}\|^2$$

$N_p$ : number of points in the less dense cloud, in the area overlapping the clouds

$\vec{x}_i$ : Point cloud "model" (considered fixed)

$\vec{p}_i$ : Point Cloud homologous "observer" (cloud rotation and translation transforms)

Once these parameters are calculated, are applied to the cloud homologous "observer" the transformation, and repeat the previous steps iteratively, until it reaches a certain threshold. To solve the equation least squares minimization using nonlinear Levenberg - Marquardt<sup>8</sup> or

<sup>4</sup> MITRA, Niloy, GELFAND, Natasha, POTTMANN, Helmut, GUIBAS, Leonidas., Registration of point cloud data from a geometric optimization perspective, Eurographics Symposium on en Geometry Processing, Nice, France, 2004.

<sup>5</sup> Li, Y, Wang, Y., An Accurate registration method based on point clouds and redundancy elimination of LIDAR data. The Proc International Archive of the Photogrammetry, Remote Sensing and Spatial Information Sciences. Vol XXXVII. Part B5, Beijing, 2008.

<sup>6</sup> BESL, Paul, MCKAY, Neil., "A method for registration of 3D shapes". IEEE Transactions on pattern analysis and machine intelligence, Vol 14, 1992 pp 239-256

<sup>7</sup> AL SHAWA, Majd, Consolidation Des Nuages De Points En Lasergrammetrie Terrestre, Nouvelle Approche Basée Sur Les Entités Linéaires, Tesis Master, École Nationale Supérieure d'Architecture de Nancy, Université Henri Poincaré, 2006.

<sup>8</sup> Fitzgibbon. A., Robust registration of 2d and 3d point sets. Image and Vision Computing, vol. 21, 2003, pp. 1145-1153

technique of singular value decomposition (SVD) proposed by Arun<sup>9</sup> in 1987 or quaternions by Horn<sup>10</sup>.

Understood the registration process, join criteria arise from the practical component, for the proper use of these processes, improving their effectiveness:

**Differences between positions by moving objects:** ICP Registration is a statistical process, the noise produced by a person, cables, etc. not significant, but in the case of large flows, or mass movement of vegetation by the wind, we recommend performing a cleaning process this data manually. In the case of the second record of *Vila Vella* we recover positions eliminated by the noise that had, to be mostly vegetation (no information facade).

**“Closed traverse” survey method:** is necessary zone control in urban projects given its length, linking initial positions with a closed end, trying to mimic the process Closed traverse<sup>11</sup>, conducted by total stations and theodolites.

**Merge in more than one direction:** The average error in the log is accumulated; it is advisable to avoid a linear direction registration with a higher tendency of information in one axis than in another. Being the junctions of roads checkpoints, and the centers of the way areas of constant review, ensure homogeneous values. Although the instrument error is greater at a greater distance, making positions from high points to confirm the registration, in the case of *Vila Vella* this process allowed us to further strengthen the model.

**Table 1: Statistics Area**

Indx	Conv	Mean	StdDev	Indx	Conv	Mean	StdDev	Indx	Conv	Mean	StdDev
2	2.3e-007	-0.000053	0.005071	18	0.000004	-0.000151	0.004524	31	0.000001	-0.000050	0.005038
3	1.7e-007	-0.000022	0.004987	19	0.000001	0.001112	0.004902	32	0.000001	-0.000399	0.005094
4	2.2e-007	-0.000003	0.004964	20	0.000004	0.000010	0.005112	33	2.0e-007	-0.000067	0.005189
5	1.3e-007	0.000032	0.004980	21	3.4e-007	-0.000076	0.005193	34	0.000001	-0.000098	0.004882
6	9.6e-008	-0.000028	0.004954	22	0.000009	0.000409	0.005287	35	9.9e-007	0.000154	0.005083
7	4.5e-007	-0.000077	0.005011	23	8.7e-007	0.000099	0.005236	36	1.5e-007	-0.000088	0.005044
8	1.5e-007	0.000179	0.004979	24	0.000001	-0.000139	0.005285	37	1.0e-008	-0.000145	0.005009
9	6.6e-007	0.000018	0.005005	25	3.0e-007	-0.000750	0.005163	38	1.4e-007	-0.000198	0.005008
10	0.000008	-0.000112	0.004873	26	3.9e-007	-0.000205	0.005090	39	6.1e-007	0.000375	0.005014
11	7.8e-007	0.000520	0.004890	27	4.6e-007	-0.000286	0.005078	40	3.6e-008	0.000909	0.005136
12	0.000001	-0.000439	0.004796	28	2.8e-008	0.000218	0.004982	41	0.000002	0.000163	0.005218
13	0.000001	-0.000088	0.005051	29	2.3e-007	-0.000380	0.005223	42	4.7e-007	-0.000161	0.005178
14	5.2e-007	0.000094	0.005078	30	0.000003	0.000038	0.005096	43	0.000009	0.000411	0.005164
15	4.3e-007	0.000105	0.005091	31	0.000001	-0.000050	0.005038	44	2.7e-007	0.000359	0.004971
16	9.0e-007	0.000076	0.005048	32	0.000001	-0.000399	0.005094	45	2.4e-007	0.000049	0.004940
17	2.2e-007	0.000229	0.005058	33	2.0e-007	-0.000067	0.005189	46	1.2e-007	0.000249	0.005205

**Source: Own**

Statistics between positions: Different Terrestrial laser scanner have different angles capture, resolution and accuracy, at the same time these may vary according to the form of scan, for example with horizontal or inclined position of the instrument (as in the case of *Vila Vella*) or simply because the distances to the scanned surface. So for each project must perform a check of the average error between positions and standard deviation achieved, growing to an

<sup>9</sup> ARUN, K. S., HUANG, T. S., BLOSTEIN, S. D., Least square fitting of two 3-d point sets. IEEE Transactions on Pattern Analysis and Machine Intelligence, vol. 9, Washington, DC, USA, 1987, pp 698-700.

<sup>10</sup> HORN, B.K.P., Closed-form solution of absolute orientation using unit quaternion's Journal of the Optical Society of America A, vol. 4, 1987, pp 629-642.

<sup>11</sup> BEDFORD, Jon, PAPWORTH, Heather., Measured and Drawn, Techniques and practice for the metric survey of historic buildings (second edition), English Heritage, England, 2009, pp 7.

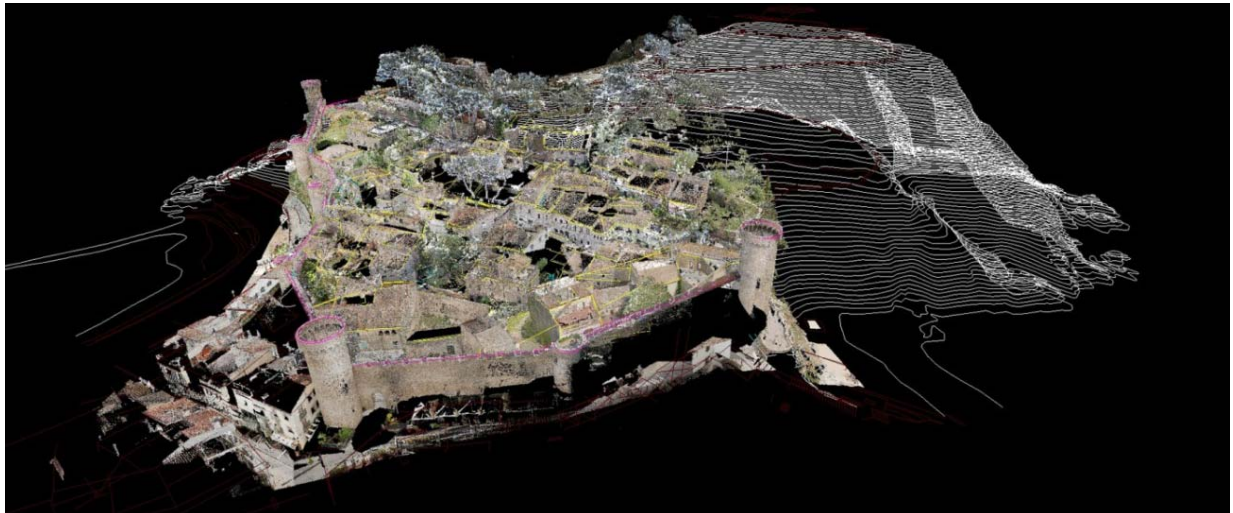
average statistical error between homogeneous positions. In the case of Vila Vella was reached 0.00055m maximum error in the mean and standard deviation 0.0055m in between positions (Table 1).

### 3.2 Georeferencing and verticality based on ICC

There are large cartographic databases Vila Vella, example of this is the database that can be downloaded from the Internet, such as: Planning Information (Zones), Cadastral Mapping WMS (General Directorate of Cadastre 2010), and data transport (eg Open Street Map), district level data (Goolzoom 2010), etc. Some of these rules are backed by national bodies such as the *Institut Cartogràfic de Catalunya* ICC.

In the case of Vila Vella 1:1000 cartography was used ICC<sup>12</sup>, for georeferencing and correct the topographic level, Figure 2.

**Figure 2:** Georeferencing and the lifting information TLS



**Source:** Own

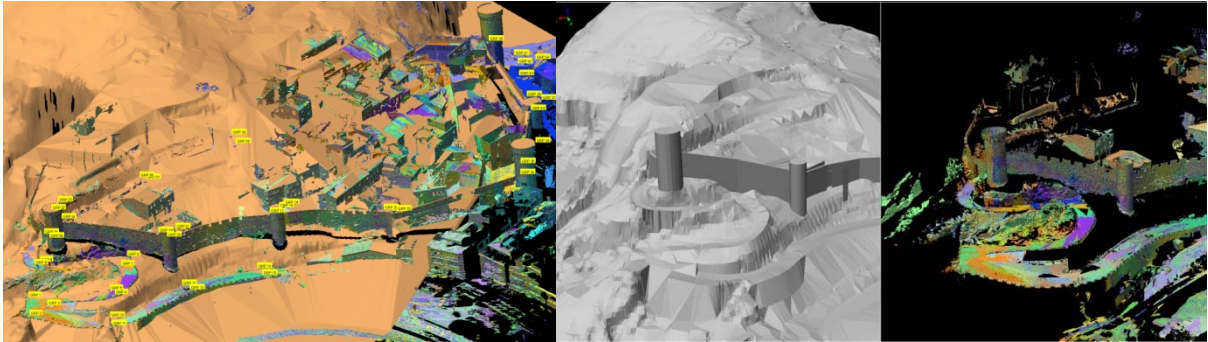
When performing a verification of this information with a preliminary record of Vila Vella, commonalities were identified: the level of roads, topography and geometry of the medieval wall, by contrast the stairs are different from those recorded in 2008 and vectors 3D houses do not correspond to actual edges of the buildings, these being the union of topographic points planes as unrelated surface (for binding of the vectors).

The georeferencing is achieved from mesh. The contours and roads became a mesh and the vectors of the medieval walls and towers became projected volumes to the ground. Parallel to this was the union of all the positions of TLS, managing to have two models, one that would be fixed based on the ICC and TLS has been rotated and relocated using 150 points coincide, Figure 3. This process allowed correct both vertical as rotation and fill information gaps with ICC data, given the mountain topography and vegetation.

<sup>12</sup>Proyecto 08,09-2004 código 00119771600, formato: SHP 3D, fecha vuelo: Agosto de 2004, fecha de revisión de campo Diciembre de 2005 <http://www.icc.cat/cat/Home-ICC/Inici/Cartografia/Documentacio/Especificacions-tecniques>



**Figure 3.** 150 points for geo-referencing information between the ICC and TLS

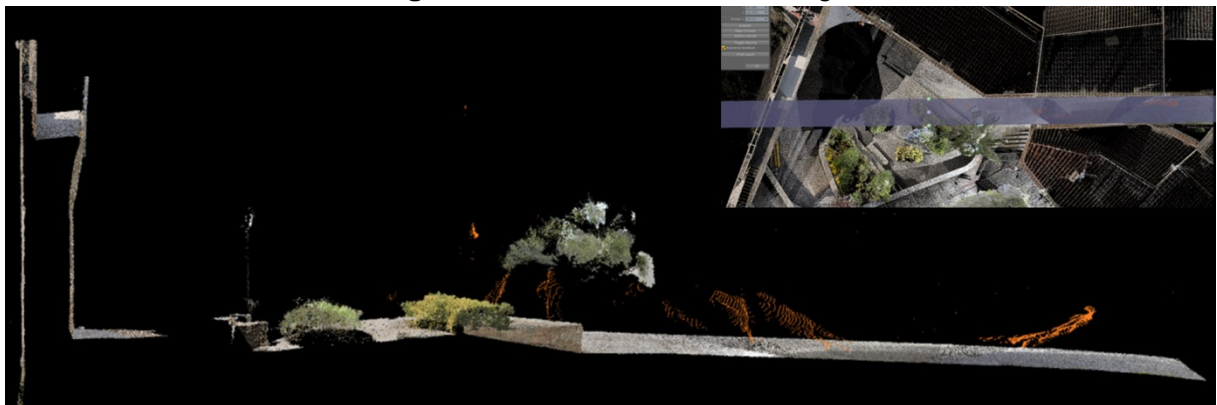


Source: Own

### 3.4 Cleaning of the point clouds

Cleaning processes automatic and manual not eliminate all of the unwanted information, and thereby given the need for a noise-free model for future analysis of the information, there were three cleaning steps. The first process is manually from scanning position, eliminating noise from moving parts and cutting data at a distance of 50 meters radius, looking facilitate registration.

**Figure 4:** Second manual cleaning.



Source: Own

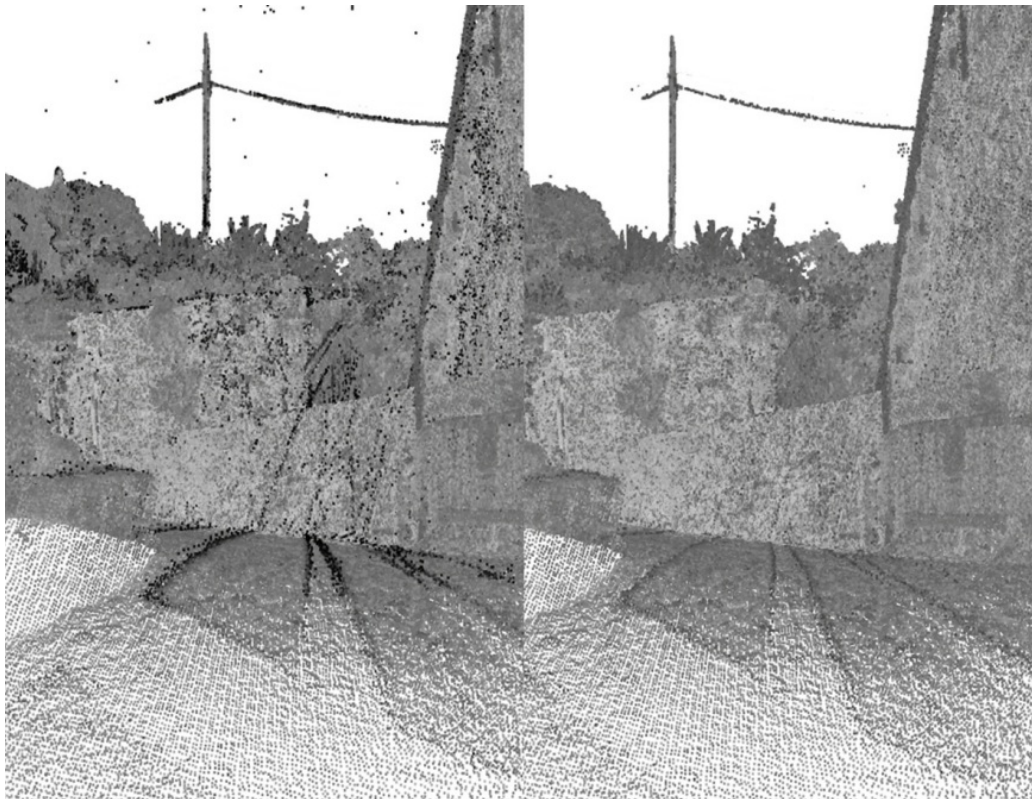
So we proceeded to a second cleaning step once joined TLS positions. The cleaning position is limited by a larger radius of 15m, with z420i Riegl scanner by reducing the resolution and definition of the objects. So we proceeded to a second cleaning step once joined TLS positions. This cleaning requires preliminary criteria, depending on the objectives outlined in the project, given its size and complexity volumetric, to extract data for areas that joining maintains consistency. For example, it was considered noise information indoors, registered indirectly. This process was carried out with orthogonal sweep every 2 meters, exporting this information as another cloud of points, figure 4, allowing a more effective manual cleaning, with better resolution with all positions, being negative for this process the time required.

Since that position is difficult to identify objects in the cloud of points at distances greater than 15m, with the scanner Riegl z420i, we proceeded to a second cleaning step once joined TLS positions. This cleaning requires preliminary criteria depend on the project you work for the goals set by its scope and complexity volume, to extract data by area of work, joining must be equal, for example noise was considered inside information housing, registered

indirectly. This was scanned in an orthogonal every 2 meters, exporting this information as another cloud of points, allowing you to recover data that was removed in error, Figure 4. Given the position resolution achieved by combining the cleaning is more effective; being the time required for this second process is a downside.

Complementary to this, and semi-automatically, the noise is decreased by the selection of a current range, a supplementary file extracting certain information considered noise, between 0.03 to 0.4 db, with a tolerance of 30%. These values were determined by consecutive tests on the selection of information and the subsequent verification model, as seen in Figure 5, where the noise intensity 11'321 file 000 points out of 208 points 317'790, without affect the main materials medieval environment, being mostly low reflectance.

**Figure 5:** Clean intensity information. Initial information Left and without predefined intensity ranges right.



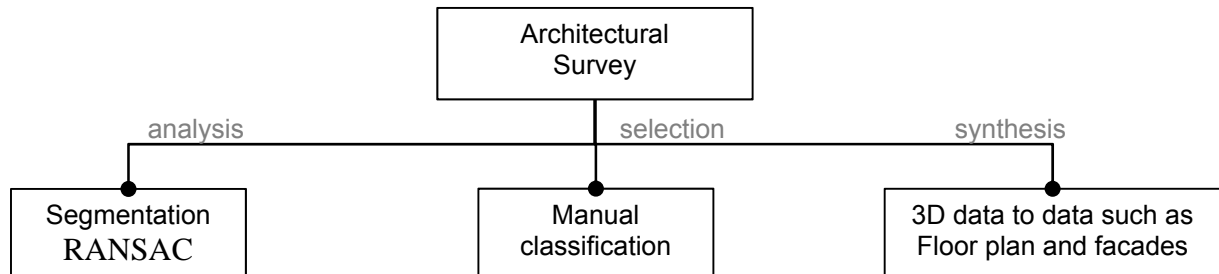
Source: Own

Finally made automatic cleaning processes, cleaning processes based on laser scanner aerial LIDAR (Light Detection and Ranging): Filter isolated points of the average of the point cloud, point groups filter out the average of the point cloud predefined, noise filter in average levels without smoothing or modification of data and reducing redundancy of points with a distance less than 0.001 m.

#### **4. Structure of the point cloud in floor plan and facades**

Surveys are of special interest to the architectural knowledge of reality and also serve to collect, organize and provide objective information to various disciplines, is "a rigorous task devoted to deep understanding of the architectural object and the formation of critical and

personal vision "<sup>13</sup>. From the analysis as a process of distinction and separation, continuing a process of selection, which allows the classification and comparison of this information, at different scales and levels of depth. Concluding with the relationship of the parties, and that architecture cannot be explained by the sum of its parts in isolation.



## 4.1 Analysis, Segmentation of point cloud

Diverse publications consider the segmentation as the first step in extracting the information from the point cloud<sup>14</sup>, given the variety, complexity, amount of information, the value of the information and the processing times required for their manipulation. The object of segmentation is to identify homogenous attributes in regions and introduce some level of organization, before the extraction of useful information<sup>15</sup>. In the case of laser data, homogeneity generally refers to the position of points in 3D, a homogeneity criterion could be the curvature or flat shapes described by a set of points<sup>16</sup>.

In recent years automated processes have been proposed, most of these techniques have been developed initially with air LIDAR data. These data are acquired 2.5D, which gives the possibility to transform the image, without risk of significant loss of information<sup>17</sup>. Differently from the point cloud obtained by terrestrial laser scanner acquired 3D<sup>18</sup>. The conversion of these clouds of points on a 2D grid could cause a great loss of spatial data<sup>19</sup>. Therefore, the image segmentation algorithms have been extended and adapted to these new data.

Publications of laser data segmentation can be grouped into two families: the first is based on the principle of fusion (or aggregation) and the second in the automatic recognition of geometric shapes. Wang, Tseng<sup>20</sup> and Schnabel<sup>21</sup> proposed approaches based segmentation algorithms splitting and merging using an octree structure, in the same context

<sup>13</sup> Opcit., SEGÚI, Javier.,

<sup>14</sup> Vosselman, George, Maas, Hans/Gerd., Airbone and Terrestrial Laser Scanning, Whittles Publishing, Scotland, 2010, pp 63

<sup>15</sup> Z. Lari, A. F. Habib, E. Kwak., AN ADAPTIVE APPROACH FOR SEGMENTATION OF 3D LASER POINT CLOUD, ISPRS 2011, Laser Scanning Workshop

<sup>16</sup> DEVEAU, M., Utilisation conjointe de données image et laser pour la segmentation et la modélisation 3D. Tesis Doctoral de Université René Descartes R, Paris, 2006.

<sup>17</sup> MASAHARU, H., Hasegawa, H., Three-Dimensional City Modeling from Laser Scanner Data by Extracting Building Polygons Using Region Segmentation Method, Proc. International Archives of Photogrammetry and Remote Sensing, Amsterdam, 2000. GEIBEL, R., Stilla, U., 2000.

<sup>18</sup> VOSSelman, George, GORTE, B.G.H., SITHOLE, G., RABBANI, T., Recognising structure in laser scanner point clouds. IAPRS, vol. 46, part 8/W2, Freiburg, 2004, pp 33-38.

<sup>19</sup> STAMOS, I, ALLEN, P., Geometry and texture recovery of scenes of large scale. CVIU, vol. 88, n° 2, New York, 2002. pp 94-118

<sup>20</sup> WANG, M., TSENG, Y., LIDAR data segmentation and classification based on octree structure. XXth ISPRS Congress, Istanbul, Turkey, 2004.

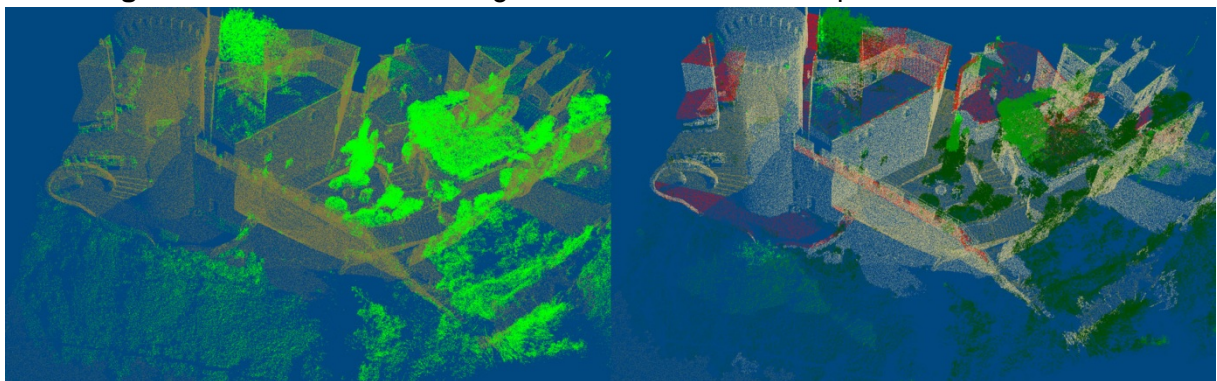
<sup>21</sup> SCHNABEL, R, WAHL, R., KLEIN, R., 2007. Efficient RANSAC for Point-Cloud Shape Detection. In Computer Graphics Forum, vol. 26, n° 2, Blackwell Publishing, 2007, pp, 214-226.



Pu, Vosselman<sup>22</sup>, Stamos and Allen<sup>23</sup> used an extension of the region growing algorithm, for the extraction of the facades of buildings with flat TLS.

In the case of Vila Vella, we analyze segmentation point cloud and open source software, in a comparison process, highlighting the concepts of classification for flat floor and ceiling surfaces, the classification based on the "roughness" of surfaces, which allows the identification of vegetation, Figure 6. These processes are mainly for aerial scanners, where the vegetation is confused with complex elements, such as windows, but this initial segmentation allows standardization of the process, but then requires a manual reorganization, emphasizing the advantages that enable these processes in the separation of ground planes with the facade.

**Figure 6:** Classification of "roughness" and classification plane of and flat roofs



Source: Pòpia

## 4.2 RANSAC Classification

RANdom SAMple Consensus, proposed by Fischer and Bolles (1981) is an iterative method for estimating parameters of a mathematical model from a set of data observed. It comes from the field of computer vision and is mainly used in photogrammetry, to find the corresponding points of a pair of images, in the point cloud registration (DARCES Method)<sup>24</sup> and is also used as geometric segmentation algorithm, due to its ability to automatically recognize the ways through data (planes, cylinders, spheres and tori), despite the noise of the same.

The RANSAC paradigm extracted random basis minimal points (Figure 7 taken 1000 points) on which the connection point search in this case the plane, whereas this number to determine the minimum geometric primitive unequivocally. The resulting shapes are tested against the data points to determine how many of the points approximate to the original form. After a number of trials, the shape that approximates most points are extracted and the algorithm continues in the remaining data.

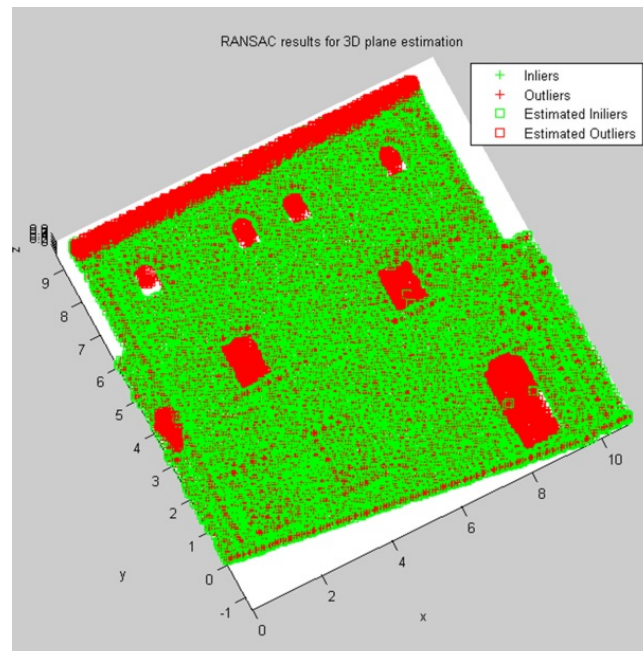
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<sup>22</sup> PU, Shi, VOSSelman, G., Building facade reconstruction by fusing terrestrial laser points and images Sensors. vol. 9, n° 6, Netherlands, 2009. pp 4525-4542.

<sup>23</sup> STAMOS, I, ALLEN, P., Geometry and texture recovery of scenes of large scale. CVIU, vol. 88, n° 2, New York, 2002. pp 94-118

<sup>24</sup> CHEN, C, HUNG, Y, CHENG, J., RANSAC-based DARCES: A New Approach to fast Automatic Registration of Partially Overlapping Gande Image, IEEE Transacions on Ptttern Analysis and Machine Intelligence, vol 21 n 11, 1999, pp 1229-1234.

**Figure 7:** RANSAC, Removing façade planes in Vila Vella, algorithms presented by KOVESI<sup>25</sup> and Zuliani<sup>26</sup>



Source: Own

### 4.3 Selection, manual reorganization

Handling classified information is divided into four types according to their limitations in terms of resolution, distribution and complexity, which is explained below and shown in Figure 8:

**Scanned surfaces directly:** Facade and medieval walls, with a homogeneous distribution of points, a resolution of 1 cm on average between points and 3 cm facade average medieval wall, with minimal occlusion given the architectural typology.

**Surfaces scanned indirectly:** The ground has drastic changes in its resolution by the distance to the scanner, the tangential scanning and has low resolution by limiting instrument angle of 80 °, and presents self-occluding surfaces as for example with low walls and steps. With complex organic shapes in street intersection.

**Capturing distant points:** The covers presents a homogeneous distribution points for roof plane, with variable resolution in relation to the capture points, near the wall 10 cm average distance between points and 20 cm on average when the record is done from the ground, presents problems of occlusion height limit scanning and volumetric change. The lack of information at altitude raises the need to use ICC information in a complementary.

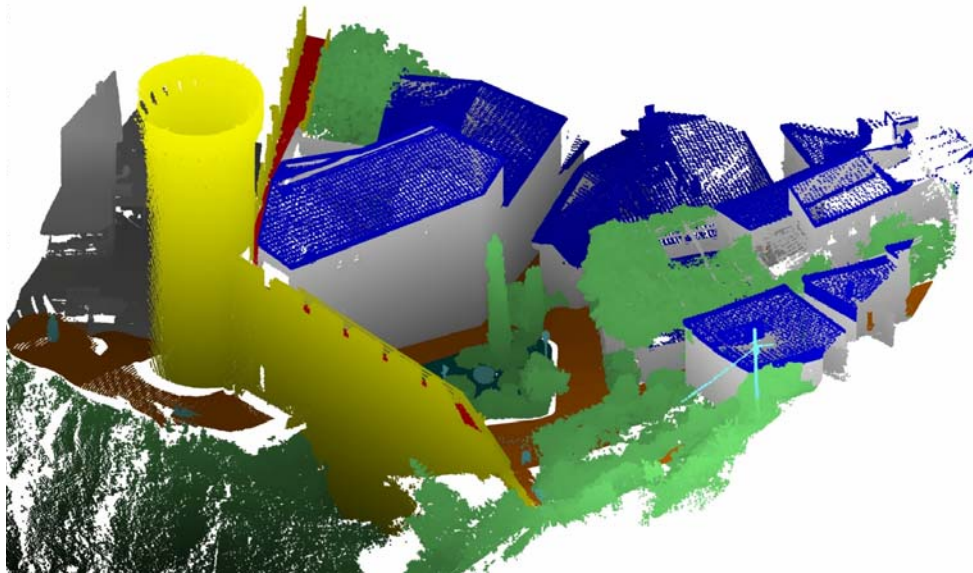
**Complex elements:** vegetation and furniture, this information has wind noise and problems with the registration edge in relation to the accuracy, intensity and color. With complex shapes that are not recorded in its entirety and with issues of self-occlusion and occlusion between elements. There are differences of information among the dense undergrowth and

<sup>25</sup> KOVESI, Peter., "MATLAB and Octave Functions for Computer Vision and Image Processing", 2006. <http://people.csse.uwa.edu.au/pk/Research/MatlabFns/index.html>

<sup>26</sup> ZULIANI, Marco, RANSAC for Dummies With examples using the RANSAC toolbox for Matlab™ & Octave and more, Enero, 2012.

tall trees. We accomplish the segmentation of the land and vegetation with automated processes.

**Figure 8:** Example of manual data regrouping TLS (Facades, medieval wall, ground, roofs, vegetation and street furniture).



Source: Own

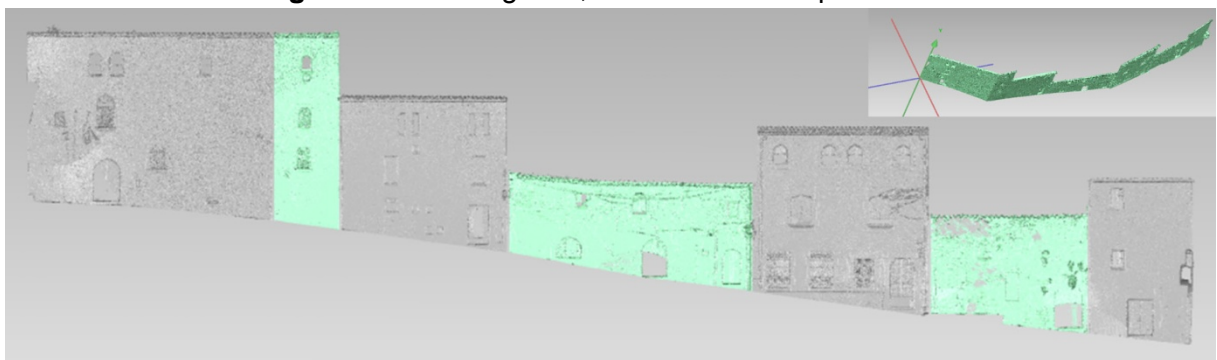
## 4.4 Synthesis. From 3D to 2.5D raster and database

When information is transmitted is shown as a representation scaled of what was recorded. Understand the limitations of scale are essential to make appropriate use of data from survey information.

### 4.4.1 Unfolding the information of the facade.

The typology of medieval walled town of Vila Vella presents specific strategies for handling information, with specific characteristics such as: maximum height three floors, flat facades without volumetric changes, the presence of low walls, covered worldwide access to housing, specific urban elements (lighting, signs, gazebos, etc.), the widening of the wall creating a gateway, the intersection of the wall with the buildings, the morphology of the towers, their access, etc.

**Figure 9:** Unfolding TLS, cloud base and split facade.



Source: Own



Each of these features determines the relationship of point cloud files generated in a structure analysis of architectural plans and facades. An example is the unfolding of facades in Figure 9. The split is done at the plot level, by detecting RANSAC higher plane, with the plane; we proceed to calculate the rotation and translation so that it sits in an exact position. Such translation and rotation information is used to modify the position of the points of the facade, this data being stored in LAS<sup>27</sup> format (point cloud).

#### 4.4.2 Construction TLS image as a database

Conversion to Raster images from point cloud data LAS has endless variations, to extract different data, like the choice of interpolation processes in relation to the objectives set. For Vila Vella we compared various processes, concluding with two lines of raster information management, a fixed scale images with ortho and another in which the raster is considered as basic information, which can extract data or combine generating new content to be studied.

**Figure 10:** Medieval wall Vila Vella. Rendering of the point cloud



**Source:** Own

As initial information ortho image is made from the orthogonal view point cloud in programs point cloud rendering, figure 10. The advantage of this process is its speed, as it requires only capture an image at a resolution determinad to keep the scale, requires the transformation of the information base and can handle large databases. Moreover it has a limited use of the data, which is explained in detail in the following summary:

Comparison management and exploitation of raster information, between Geographic Information Systems GIS and visualization TLS programs:

**Pixel size resolution:** The resolution of the preview image depends on the scanning process and instrument. The resolution from GIS calculation is based on more detailed areas, performing interpolation processes for areas with gaps. The point cloud visualizers

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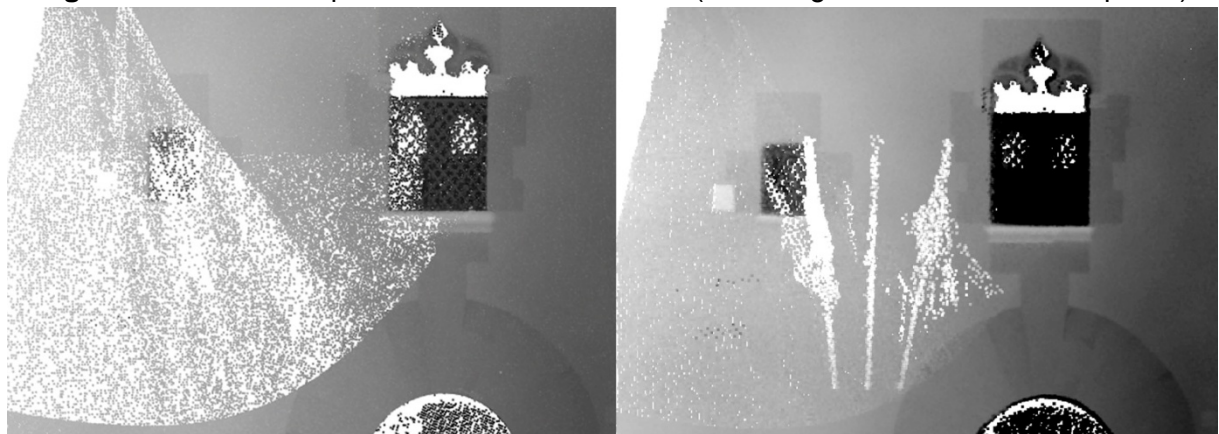
<sup>27</sup> ALBACETE, Antonio San José., Procesamiento de datos LiDAR con ArcGIS Desktop 10, Tesis del Master En Tecnologías De La Información Geográfica, Universidad Complutense De Madrid, Madrid, 2011

use a point size that averages the detail in the image, reducing the detail in areas of greater detail and filling data gaps by increasing the size of the point.

**Handling data gaps:** GIS for working on the data, ignoring the information gaps in the interpolation process. Viewers of point cloud mixed data with a background color, sometimes blurring the pixels with filters.

**Filtering the base image (interpolated data):** They are extensive manipulation tools from GIS Raster: from interpolation processes aimed primarily at generating digital terrain models, specific applications for aerial scanners (based on LAS files) to the manipulation a raster point, process allow monitoring of the data without interpolation, complementary to this, there are processes and operations that allow both as complete information change, interpolating the pixel information in relation to nearby pixel in a controlled way, being broad field of development from the discipline of remote sensing and aerial scanners LIDAR. The point cloud visualizers using filters, thereby example antialiasing filter, but does not improve or add information, limiting further processing raster analysis as application data or image processes techniques, figure 11.

**Figure 11:** Viewers of point clouds and raster GIS (Low Neighborhood radius of 3 pixels)



**Source:** Own

**Raster image overlay:** Information Orthogonal Cleavage of TLS information on facades, plants, and complex elements, allows to find the exact values regarding its orthogonal alignment, for example in the case of facade, finding the major plane with RANSAC processes, ensures the rotation and translation information corresponding to the average of the plane, meaning that there is a strain on the facades. For point cloud viewers, the camera is positioned orthogonal to two or three points of alignment visually selected on the facades, with the possibility of a wrong selection or alteration by selecting points more noise.

**Orthogonal information:** The information unfolding in front TLS, plant, and complex elements, allows to find the exact values as to their orthogonal alignment, for example in the case of the facade, to find the highest level RANSAC processes, ensures the rotation and translation, corresponding to the average of that information to the 0.0 level, meaning that there is a bulge on the facades. In the case of generating images from viewers TLS, the camera is positioned orthogonally with two or three alignment points, selected visually, on the facades, with the possibility of an erroneous selection or alteration by selecting points in greater noise.



**Select information to be extracted:** GIS allow you to select which is the value to be drawn in relation to the position of (minimum, maximum, average, sum, standard deviation, etc.). The point cloud displays rendered through a camera, which only takes the values of points that are closer, preventing meet minimum data such as window without the elements to be superimposed to it.

**Scale information:** GIS programs for working with float values, up to 32 bits, allowing you to keep the original values of depth range images. In contrast images from the display allow only 8bit values.

## 5. Raster data management from the TLS

The facade structures or vegetation are not automatically recognized by machines, by contrast human capabilities allow easy recognition of the elements of the urban space, as the position of the planes, the shape, color and typology<sup>28</sup>. It is therefore necessary to create criteria for identification of these elements semi-automatically, by classification properties<sup>29</sup>.

### 5.1 The color and intensity information, the analysis of the material

The intensity is a measure of the strength of the electronic signal, obtained by the transformation and extension of the reflected optical power. This is mainly caused by the reflectance of the scanned surface, where this reflectance is the ratio of backscattered radiation incident on the wavelength of the TLS, in their angle of incidence. In aerial scans this information is widely used, to the point of being the first step to explore<sup>30</sup>, which is in principle also possible with terrestrial scanners.

It is complex in the scanner application z420i Riegl since some problems limiting its direct examination, such information is not mapped linearly, also the effect of the saturation and variations of emission are unknown. However, they have the potential for more sophisticated applications such as registration or classification by the material surface property<sup>31</sup>, as shown in Figure 12.

The digital color information has been widely used for the recognition and recording pathologies<sup>32</sup>. Looking to get precise information: materials, distance measures, areas of architectural entities, and statistical documents that verify the accuracy achieved. Where metric images, and the extracted information can be given directly as layers or levels of information in GIS and CAD systems.

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<sup>28</sup> PU, Shi, Extracting Windows From Terrestrial Laser Scanning, ISPRS Workshop on Laser Scanning and SilviLaser, Espoo, Finland, 2007.

<sup>29</sup> BOULAASSAL, H, Automatic Segmentation Of Building Facades Using Terrestrial Laser Data, ISPRS Workshop on Laser Scanning and SilviLaser, Espoo, September 12-14, Finland, 2007.

<sup>30</sup> ULLRICH, Wagner, Gaussian Decomposition and Calibration of a Novel Small-Footprint Full-Waveform Digitising Airborne Laser Scanner. ISPRS Journal of Photogrammetry and Remote Sensing, Volumen 60, Issue 2, Abril, 2006, Pp 100-112.

<sup>31</sup> PFEIFERA, Norbert, Investigating Terrestrial Laser Scanning Intensity Data: Quality And Functional Relations, "International Conference on Optical 3-D Measurement Techniques VIII", ISBN: 3-906467-67-8, 2007, pp 328 – 337.

<sup>32</sup> LERMA, José Luis, Clasificación multiespectral de imágenes digitales para el reconocimiento y caracterización de materiales y patologías en fachadas arquitectónicas, Tesis Doctoral, Departamento De Ingeniería Cartográfica, Geodesia Y Fotogrametría, Universidad Politécnica De Valencia, 1999

**Figure 12:** Handling of color and intensity. A) Improved RGB and intensity from GIS. B) Problems with homogeneity of information from point cloud displays. C) Classification RGB, Mahalanobi Distance, Object base from ENVI Zoom.



Source: Own

## 5.2 The depth maps information

The depth data is extracted from XYZ, from two scales, the first without any alteration from the basic information, including the deformation from the front relative to a plane, as the detail from the surface texture, Figure 13. The second interpretation of depth is a result of the subtraction of a plane with the general shape of the facade, to its corresponding depth map, focusing only in the detail of the facade (explained in depth in future articles).

**Figure 13:** Raster minimum depth of Oliver Street

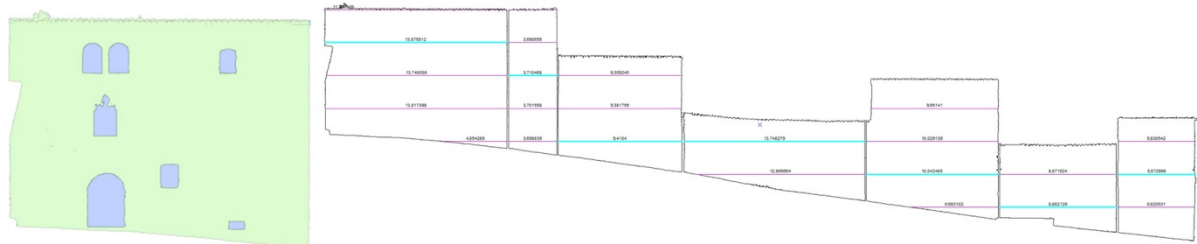


Source: Own

### 5.3 Classification and vectorization of complex surfaces

The color noise, normal and intensity limit a direct classification, contrary to this, the depth information allows an initial division of raster data, enabling to limit the information to a particular range, segmenting walls, windows - doors and interior elements walls, one example is sorting and conversion in areas of the facades vector in Figure 14.

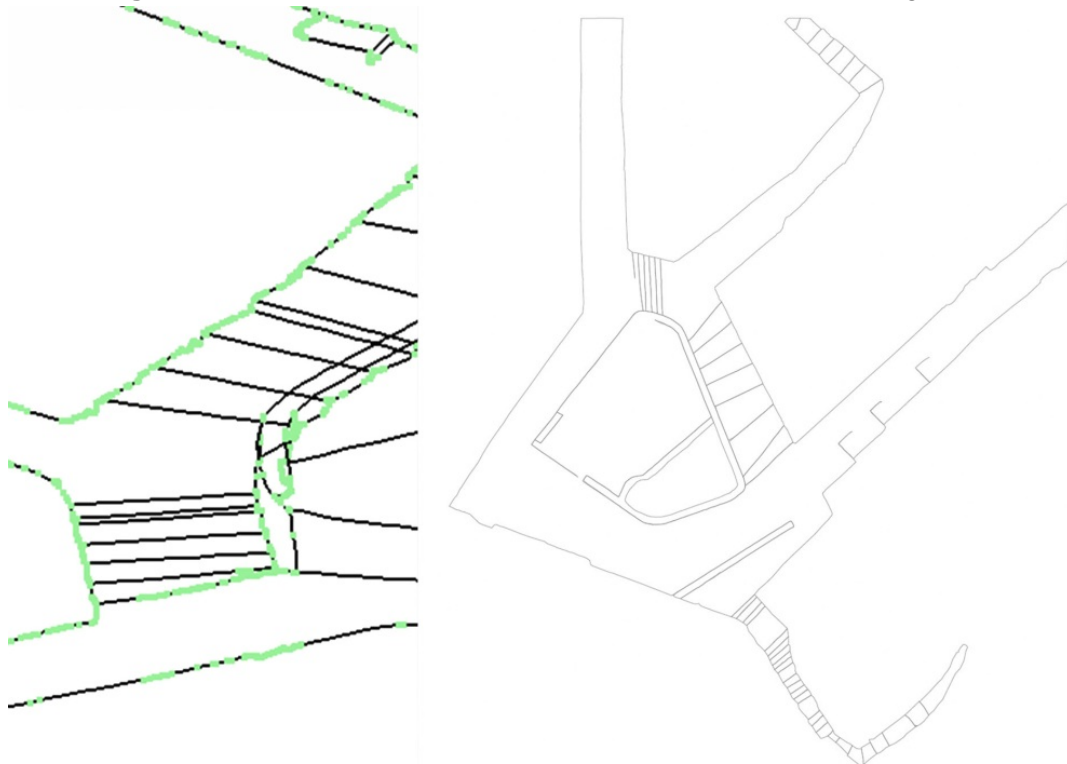
**Figure 14:** Left: a classification vector area of depth. Right: intersection of lines every 2 meters with vector areas, defining the major length of facade for each plot.



Source: Own

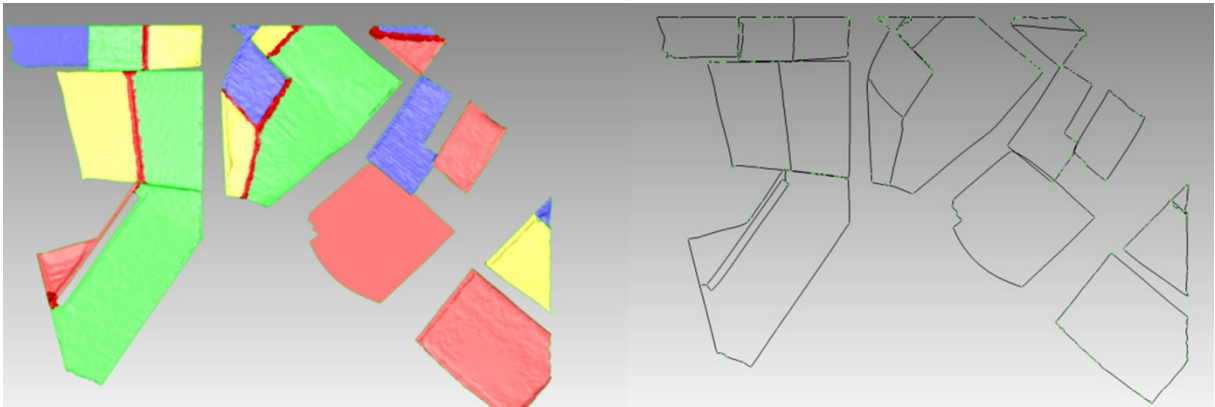
Moreover organic forms require more complex processes, which have been explored as aerial images from LIDAR scanners. Given the complexity of streets Vila Vella, a methodology was developed, based on the triangulation of the information on depth maps and the elimination of certain inclination surfaces, semiautomatic manner, as shown in Figure 15. Complementary processes were also performed as orientation classifications, finding the points at which slopes intersect, as in Figure 16, with the roof surfaces.

**Figure 15:** Semi-automatic vectorization of complex surfaces ground



Source: own

**Figure 16:** Limits of the planes and intersection of planes (roof surfaces)



Source: Own

**Low vegetation:** in this category are considered green areas under 3m above ground level, including vegetation on pergolas and small trees. These elements have data gaps and the noise by the movement of the blades, which hinders their analysis, whereby the resolution is 10 cm and with the pixel interpolation filter applied. This was done after a supervised classification Minimum Distance in five regions of interest (ROI), based on vegetation height, in relation of two maps, the minimum and maximum raster including the ground. This classification became vectors, making these 5 values measured independently in relation to its area and complexity, Figure 17.

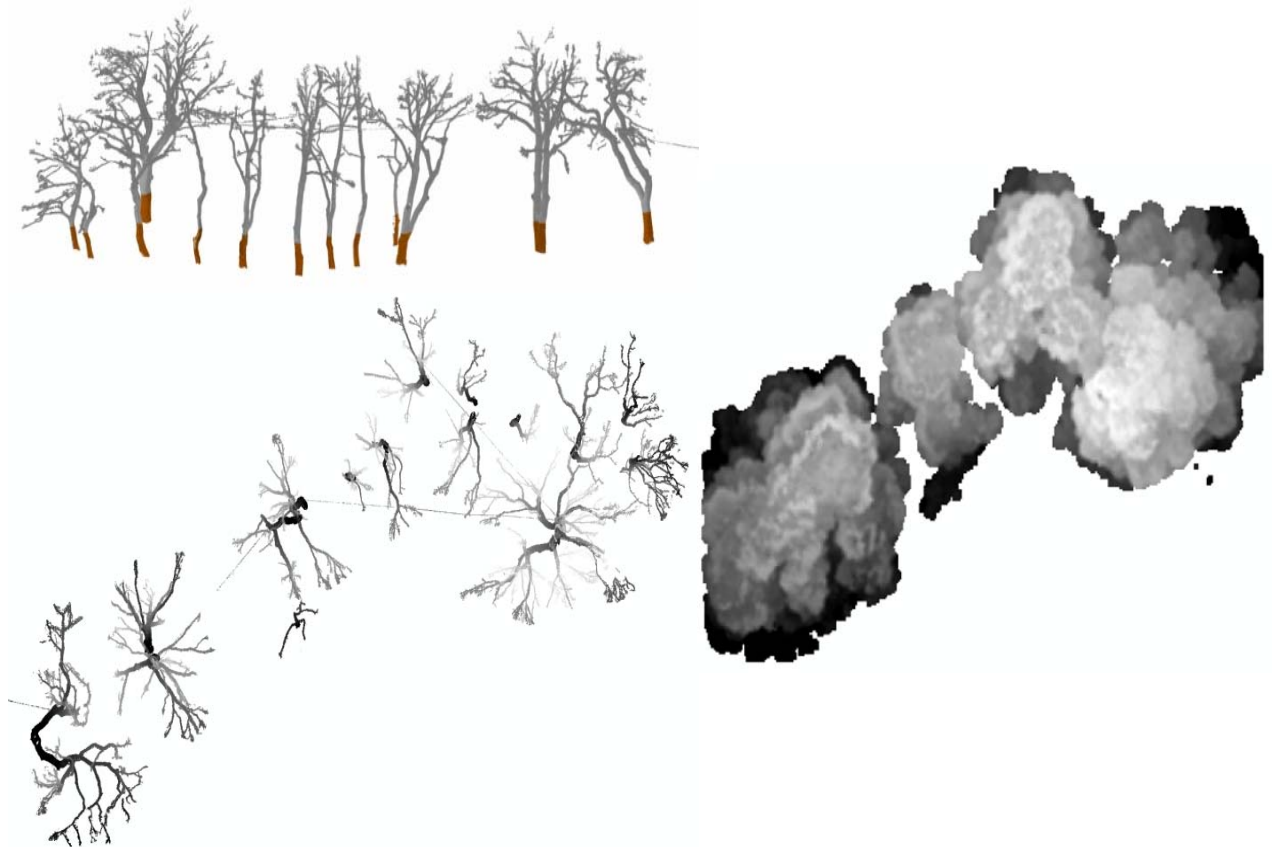
**Figure 17:** Classification Minimum Distance (5 ROI) and conversion to vector areas



Source: Own

**High vegetation:** Considering more than 3 meters. Due to its characteristics needed a formal division in stem and leaf. The area of the trunks at the same time was sectioned in two, cutting the information that was less than 1 meter above the ground (to find the center of the trunk at its base) and opted for transform the point cloud data to facade and plant. Parallel to this the sheets are considered as a continuum, a vegetal mass that can be measured in volume and area occupied by raster operations between images of minimum and maximum, as shown in Figure 18.

**Figure 18:** High vegetation in facade and floor. Left trunks, leaves right treetops



**Source:** Own

## Conclusions

The terrestrial laser scanner technology generates a very complex database, both in amount of information, and its structure, requiring segmentation processes and reorganization of information, according to the case study approach.

In the Vila Vella project, information was grouped according to the characteristics of the data and the typology of the medieval urban center, seeking his plan and facade synthesis by 2D and 2.5D. Allowing for data combination imitating multispectral imaging processes, in the rigorous creation of new databases, reaching a point where such information can be transformed back into three-dimensional point's models, knowing at all times the loss and improvement of the data.



Since this process is a manipulation of the data, it is necessary to minimize the loss of information based on the given resolution and quality of the initial information, beginning with the registration process validation, the classification of information in a standardized form and the correct interpolation of the data, which depends on the stated objectives, either as Digital Terrain Modeling or image processing, generated by the conversion of point data to raster.

This information in 2.5D images facilitates the application of algorithms, compared to the clouds of points in three dimensions, allowing the efficient implementation of image processing with standard processes, widely studied in computer vision, allowing the linking of various sources of information with multiple layers of images, through GIS and Remote Sensing.

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