REHAB 2017

Proceedings of the 3rd International Conference on Preservation, Maintenance and Rehabilitation of Historical Buildings and Structures

Edited by

Rogério Amoêda
Sérgio Lira
Cristina Pinheiro

green lines institute
for sustainable development

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Braga, Portugal
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Foreword

REHAB 2017 - 3rd International Conference on Preservation, Maintenance and Rehabilitation of Historical Buildings and Structures aimed to proceed with the discussion on built heritage and the preservation of its legacy that was established in the previous editions of the event. The importance of conservation of historical constructions (built landscape, urban fabrics, buildings, and engineering works) are of utmost importance to preserve the cultural references of a community and was deeply discussed in March 2014, in Tomar, and July 2015, in Porto.

Under the main topics of discussion, subjects of preservation and rehabilitation methodologies and technologies, as well as the importance of the economic and social impacts of preservation practices were covered as the main leading guidelines for the conference debate. Furthermore, different communities' scales (local, regional, national or even worldwide) and authenticity interpretation raise different questions and approaches, and therefore different solutions that are worthily to study, to compare and to experience. The sustainability approach was covered once more, highlighting the importance of the commitment between heritage preservation and technical requirements related to its occupancy and use, such as energy efficiency or materials recovery. Inclusivity was also an important aspect to be discussed as public historical sites and buildings need to be adapted to receive different kind of visitors (children, elderly or handicapped persons) and to establish an adequacy with the perceiving of the physical environment and information contents.

A new chapter was included in this edition of *REHAB 2017* and Earthen Buildings were brought into a particular approach highlighting the complexity of their preservation, maintenance and rehabilitation. Earthen buildings techniques are in many cases of a great importance for local economies and access to housing.

Authors submitting papers to *REHAB 2017* were encouraged to address one of the above mentioned topics of the Conference by providing evidence on past experience and ongoing research work. As a result, *REHAB 2017* welcomed a significant number of papers and presentations addressing field work and case studies but also theoretical approaches to historical buildings preservation and conservation. As in past editions of this Conference, *REHAB 2017* also gave stage to early stage researchers and students willing to share the results of their research projects, namely post-graduation projects and doctoral projects. *REHAB 2017* received a significant number of such proposals the quality of which was confirmed during double-blind review.

We would like to express our gratefulness to all the partners of this edition of *REHAB* who joined the effort to make a significant Conference. Our special word or recognition to the Ministry of Culture – Regional Directorate of Culture North, Museum D. Diogo de Sousa, Monastery of Tibães, Instituto da Habitação e Reabilitação Urbana, Portuguese Order of Architects, Portuguese Order of Engineers North, Association Centro da Terra and Projecto ReVer of the Unversity of Minho. As media partners of the event we would like to thank *Construção Magazine*.

Last but not least, a special word of recognition to the Municipality of Braga that assisted the Organising Committee in all manners.

The Organising Committee also expresses its gratitude to all Members of the Scientific Committee who reviewed the papers and made suggestions that improved the quality of individual work and the over-all quality of the event.

The Editors

Rogério Amoêda
Sérgio Lira
Cristina Pinheiro

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Contents

Chapter 2 - Seismic behaviour of historic buildings

Chapter 3 - Preservation and rehabilitation of historic buildings and structures: case studies

Chapter 4 - Preservation and rehabilitation of historic centres

Chapter 5 - Authenticity and built heritage

Chapter 7 - New materials and products for the rehabilitation of historic buildings and structures

Chapter 8 - Sustainability principles and practices in the rehabilitation of historic buildings and structures

Chapter 1

Technologies for inspection and monitoring of buildings performance and pathologies

Automatic recognition of materials from laser-scanner survey data by the reflectance method

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ABSTRACT: One of the most common techniques for surveying architectural heritage today is the laser scanner. With this technology a point cloud is obtained which, after being processed by computer, results in a geometric mesh, and ultimately a three-dimensional model. But laser scanning delivers also, as a byproduct, the value of the reflectance of the documented surfaces, which is the quotient of the energy of the emitted laser beam (by the machine) divided by the energy received after being reflecting on the surface of the measured object. This value varies according to the angles of incidence and reflection of the beam, but also on the optical and surface properties of the materials on which the laser light is reflected. This latter characteristic has led to hypothesize that the different materials that compose the surveyed surface can be individualized and automatically recognized. After studying similar cases in the scientific literature (made with natural light, with flights and LIDAR, etc.) we have tried to see if this assumption could be confirmed experimentally, with promising results. In this work, we explain the evidence and the methodology of the experiments performed to test the validity of this hypothesis.

1 INTRODUCTION

The use of laser scanner in historical heritage studies is a well established practice that already has a large record of experimental and bibliographic literature, which analyzes it from multiple facets.

Its potential to determining the position and geometry of any given item is well known , usually with a subcentimetre precision.

But measurement is not the only information that can be obtained from a laser scanner. In the process of capturing points other parameters can be read, such as the RGB color value (if the scanner is associated with a camera), the normal value of the readings, and the value of reflectance. This last value (i.e. reflectance) is what will be discussed in this paper.

Reflectance is simply the energy value of the laser pulse that returns back to the emitting device (laser scanner) once this has impacted on the area of study. We must not forget that the laser scanner technology is based precisely on the ability of a laser beam to stay coherent once it has bounced on a surface, allowing a reading of this reflection, and thus, the calculation of the distance between the emitter and the point of impact.

Despite the ability to maintain its consistency and not dissipate, part of its energy is scattered as a result of the reflection on the object (diffuse reflection); and another part is partially absorbed by the surface material. For this reason, the beam always returns with an lesser energy than that with which it was emitted. Only in the case of a theoretical perfectly reflective surface -- the case of a mirror-- that has been scanned perpendicularly and at a small distance, the loss of energy might be considered null. Reflectance is quantified as a percentage or a ratio, dividing the value of the received energy by the energy value of the output pulse. Thus, reflectance is typically a value from 0 to 1, although the scale of expression of this percentage varies depending on the software and hardware used.

The energy loss is determined by various elements, which are basically:

a) the distance between the laser scanner and the surveyed object: when the object is far the emitted pulse travels a larger distance through the air in the atmosphere, and it is subject to losses, noise, etc. Therefore, less energy will reach back the emitting machine.
b) the angle of incidence of the beam on the surface: Most of the light emitted by the lsaer scanner is reflected in a different direction, and only a small fraction of the diffuse reflection is redirected towards the origin point. The returning energy will be greater when the incident angle comes closest to perpendicular.
c) the nature of the surface: colour, roughness and material of the surveyed object also affect the angle and the amount of the reflected beam.

It is this last property that has allowed us to use reflectance as an analysis tool of surface types (Fig. 1).

There exist several studies in this area since the end of last century, focusing mainly on visible light. Maybe, the best known experiment is the joint work of the universities of Columbia and Utrecht (Dana et al., 1997 and 1999), which measured the reflectance value of visible light, emitted by controlled light bulbs, on different materials with 60 different angles. The reflected light was captured with a digital camera, and the pixels analyzed and their intensity transformed into a reflectance value.

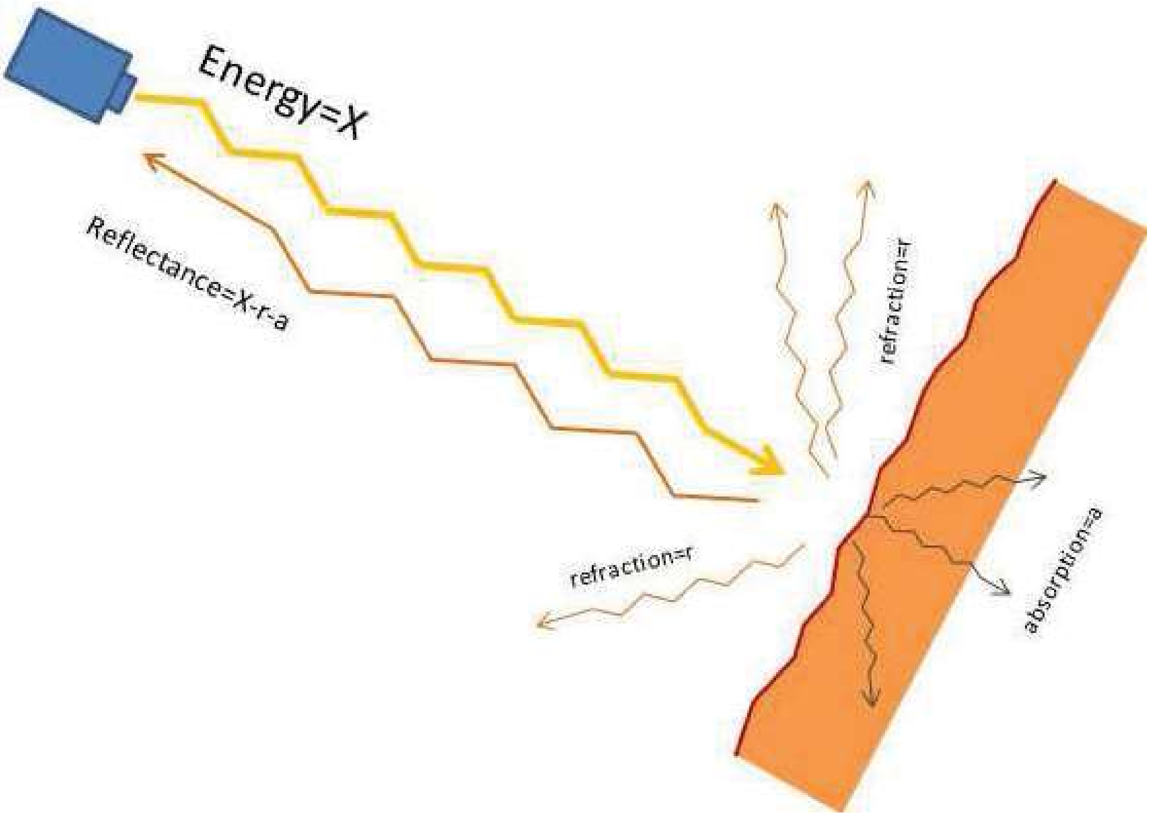

Figure 1. Graphic of reflectance.

In 2005 the work of Buill and Núñez (Buill et al., 2005) was published, which analyzes the behavior of reflectance, under controlled conditions, of several different color painted surfaces, also read from different angles. A similar experience was published by (Pfeifer et al., 2007), which carried out a statistical study of the response of six materials in different conditions of distance and angle, being reflectance one of the values analyzed.

These works --and others-- were able to analytically determine that there was a correspondence between the morphology of the surface scanned and the value of laser reflectance. This has enabled studies of practical applications such as the doctoral thesis of R. Pérez Álvarez (Perez, 2014), which unsuccessfully attempts to apply reflectance as a backup system for the detection of mineral veins in mining exploration; or the ministerial project SITEER (*Supervisión Inteligente de Túneles mediante Estudios de Emisividad y Reflectáncia*)--funded with FEDER resources—which proposed the analysis and diagnosis of the status of tunnels combining the readings of thermal imaging and laser reflectance (www. SITEER.es) --these two are a few examples in our closest geographical environment.

2 PREVIOUS STUDIES - WORKING HYPOTHESIS

Since 2006, the Catalan Institute of Classical Archeology (ICAC) and the School of Architecture of the University Rovira i Virgili (URV-ETSA) collaborate on various projects aimed at the documentation, the analysis and the study of architectural heritage, focusing mainly on the preserved remains of the ancient Roman city of Tarraco (Solà-Morales et al 2014). These works have lately materialized in the form of a ministerial MINECO project (HAR2012- 36963-C05-02) which will be ongoing until 2019. Most of these collaborations have included documentation of architectural geometric study using laser scanner.

The software for the processing of point clouds, typically generated by laser scanners, allow the view of such point clouds in different forms: natural color, gray colored patterns, and colored reflectance. In the latter, the software assigns a chromatic scale to reflectance values, rendering giving a false color image. For example, the lowest reflectance value is assigned a dark red, whilst the highest is a bright yellow, and all the values in between are a gradient between both colors. This colored visualization of reflectance allowed us to observe how often material and typological differences of the documented surfaces are clearly visible in the color-values of such reflectance images (Fig.2). With this intuitive and subjective method we could individualize pavements, metal street furniture, the pictorial decoration of facades, window frames, doors, people, and, among other things, different types of wall structures.

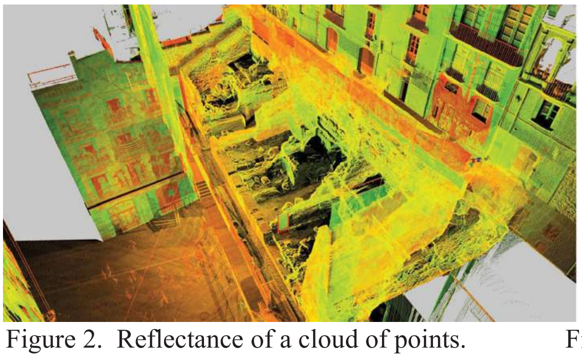

Figure 2. Reflectance of a cloud of points.

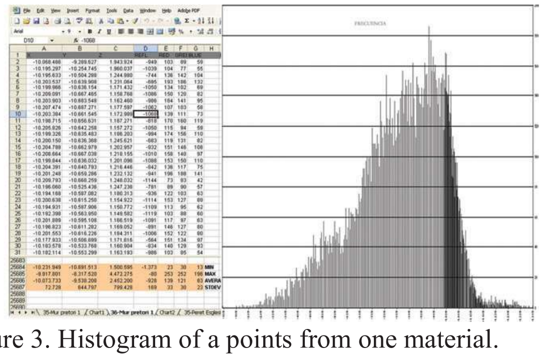

Figure 3. Histogram of a points from one material.

This visual observation allowed to set up a working hypothesis which stated that the value of reflectance could be used to discriminate among different types of surface, and thus being able to map, in automatic or assisted mode, a given area of study. If this hypothesis were valid, a very powerful analytical tool could be designed, to help in the documentation and study of historical architecture. Not surprisingly, in this

discipline, all studies are born from an individualization of elements that make up an architectural object, and which are a result of its own history. This individualization can identify different periods of construction, the actions that have been carried out on it (both subtractive and additive), and its mechanical and technical characteristics, which enables the diachronic study of the building (Parenti 1988 and 2001). This individualization is normally done manually and based on macroscopic observations, and as of today no method has been defined to automate, albeit partially, this process of analysis.

The confirmation of the working hypothesis would combine the potential of data capture systems --in this case, laser scanner-- with the analytical study of objects, which would be the starting point of an Assisted Archeology of Architecture (AAA). It is not intended to create a system that fully automates the reading of architecture; the experience and "clinical eye" of the analyst can hardly be automated, but simply create a tool that simplifies the analytical process and is able to provide new information from not visible (or barely visible) features.

In short, the assumption or hypothesis on which the work was carried out was:
"The study of the value of the reflectance of the laser scanner can discriminate and identify differences in architectural materials from the typology of the various elements that compose it."

3 WORKING PROCESS

3.1 *Reading data*

The surveying of surfaces with a laser scanner generates an ASCII file in which each line corresponds to a survey point. The data are further developed in different columns that state the values of the position x, y, z coordinates; the value of real color redings (usually in the form Red, Green, Blue) and the reflectance value, given in percentage format. The latter, according to the software that generates the file may have values that go from 0 to 1, from 1 to -1, from 256 to -256 or -1536 to 1536. In all cases, the lowest value represents a zero reflectivity, meaning that the beam has lost 100% of the emitted energy, while the highest value returned represents the return f the entire issued energy.

The following table shows an example of how a laser scanner point group is structured, with a scale from 0 to 1.

Table 1.

Xo	Yo	Zo	Refl	Red	Green	Blu
-3.259384	-6.638931	7.398300	0.332891	83	79	54
-3.259750	-6.639633	7.406479	0.370977	86	78	55
-3.258713	-6.637527	7.411575	0.373907	111	99	75
-3.257858	-6.635757	7.417007	0.408087	120	108	84
-3.257278	-6.634598	7.423111	0.363897	135	123	97
-3.258377	-6.636826	7.433029	0.426886	141	131	104
-3.257767	-6.635574	7.439224	0.412970	123	116	87
-3.257309	-6.634598	7.445450	0.419074	129	124	94
-3.256302	-6.632492	7.450546	0.417121	144	141	108
-3.258347	-6.636703	7.462723	0.432013	133	133	99
-3.259659	-6.639359	7.473190	0.325078	118	118	84
-3.260757	-6.641556	7.483139	0.392950	120	117	84
-3.261368	-6.642807	7.492050	0.398077	111	108	73
-3.259567	-6.639145	7.495407	0.402960	125	121	86
-3.258987	-6.637924	7.501541	0.328984	124	109	76
-3.260147	-6.640244	7.511673	0.232792	133	117	83
-3.259781	-6.639481	7.518326	0.243290	134	120	85
-3.260757	-6.641495	7.528122	0.244755	137	124	89
-3.261520	-6.643021	7.537399	0.227176	121	108	73
-3.264084	-6.648209	7.550858	0.287968	106	93	59
-3.262497	-6.644974	7.554733	0.399054	100	85	52
-3.260757	-6.641434	7.558243	0.393927	124	111	79
-3.259689	-6.639267	7.563339	0.404913	119	108	76

4 THE VALUE OF THE REFLECTANCE OF A CERTAIN MATERIAL

At first we considered the possibility that there was a direct correspondence between the (direct) value of the reflectance and the type of surface. Put another way, similar reflectance values should correspond to similar types of surface. If this was confirmed, it would be possible to make typological classifications of surface materials from direct comparisons only of this value. In 2015 we performed various tests based on data obtained in the field and in an uncontrolled setting, using a Leica C10 laser scanner. The C10 is a time-of- flight laser scanner, with an accuracy of 4.5mm every 50 meters, and a 3rd class laser with a wavelength of 532nm.

The analysis of the ASCII table showed, however, that there was a high diversity of reflectance values within any given material. In fact, in the above table, which corresponds to a sample of a single material, shows that the value of the reflectance varies from 0.232792 to 0.426886. In the same way, we noted that similar reflectance values were documented in parts of the file that corresponded to different materials. These two facts invalidated our first idea.

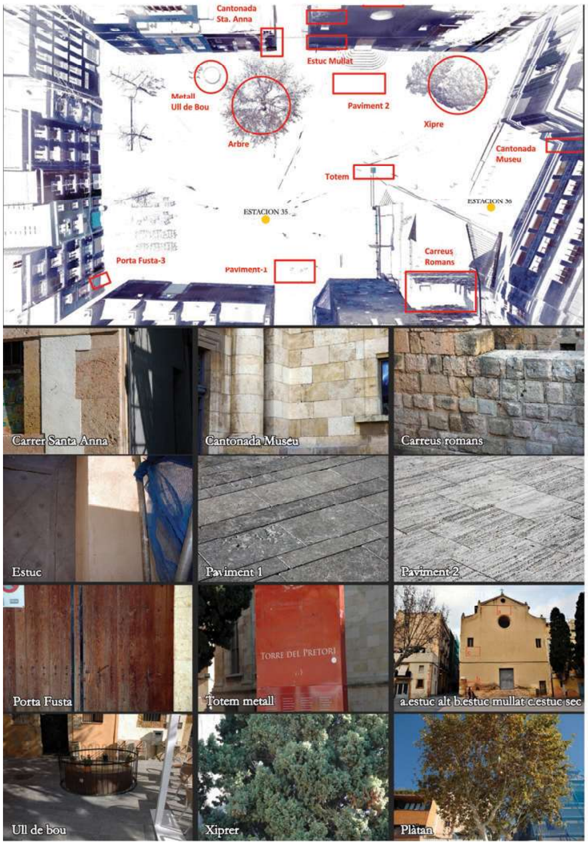

Figure 4. Materials used in the 1st experimentation.

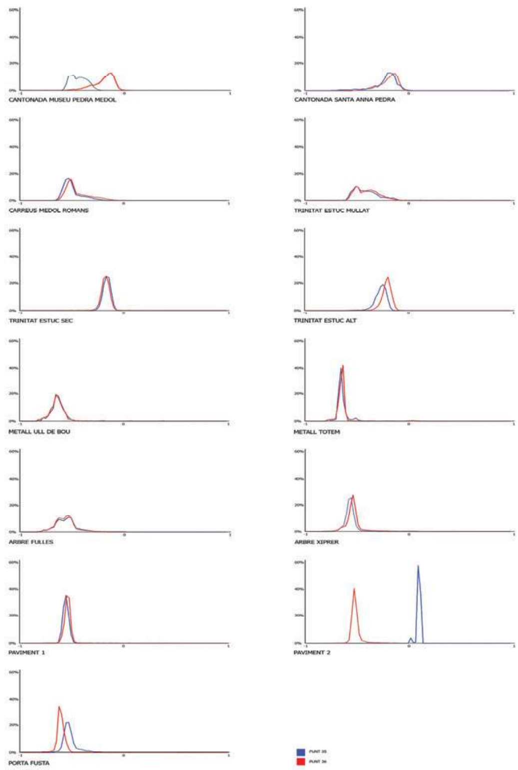

Figure 5. Histogram of the materials.

Faced with the confirmation of the impossibility of this approach we considered that the assessment of difference was not given by a specific value --which could vary depending on a number of causes we could not control-- but by a statistical analysis of a large number of points of the same type of surface surrounding the surveyed point.

In this train of thought, we took a dataset consisting of reflectance readings from of a few hundred points of the same material, from which drew a histogram distribution (Fig. 3) which define a curve akin to a bell curve. We also calculated the arithmetic mean, the standard deviation, the median and the mode as a way to characterize the histogram curve.

Taking advantage of the data obtained in the previous surveys with laser scanner (in this case the Plaça del Rei Tarragona) this analysis and diagramming was repeated in 12 samples of surface segments: 2 of stone (ashlar), 3 of stucco (normal, wet, old); 2 of different metals (painted, rusted); 2 of different vegetation (trees, mainly), 2 of travertine paving; and 1 of wood (door with no paint). The surfaces tested were between 400 and 600cm^2 and had an average resolution of 1 point every 1.5cm., which generated samples of between 15,000 and 20,000 points. Each surface was sampled with readings from two different stand points, in order to see the effects of the value of distance and angle (Fig 4).

The analysis of the curves generated through the histograms allowed us to observe that the samples of similar materials gave similar shaped curves, albeit these curves where different in size and in horizontal position when compared to the same material samples obtained from two different scans (Fig. 5).

From this very first experimental approach were draw the following conclusions (Solà-Morales et al in press):

- It is the statistical distribution of the reflectance values that describe the a typological difference among the surfaces analyzed.
- Any set of points of the same material presents a statistical distribution feature. Indeed, on the graphic level, the drawing of the bell curve of the histogram is exclusive and representative of each surface type.
- Like surfaces will yield like curves.
- The angle and distance of the measurement affect the value of the reflectance. However, the same surface material renders identical curve shapes, but larger and/or displaced at the base of the chart.
- Humidity affects the value of reflectance significantly, altering the profile of the histogram.

These findings gave rise to assume the validity of the initial working hypothesis; the value of the reflectance could be used to typologically discriminate the documented surfaces with laser scanner.

5 CONFIRMATION OF THE VALIDITY OF THE PRELIMINARY RESULTS

To confirm these preliminary results we designed a second experimental test. This time around, the studied data had been generated with a Leica laser scanner P30. This is a device that combines the flight-of-time with wavelength to set the reading distance, and uses a Class 1 laser of 1550nm, with a precision of 0.5mm at 50 meters. The study object was a segment of the facade of the old hospital of Sta. Tecla in Tarragona, scanned in 2016, about 2x1 meters and containing different materials: anodized aluminum, white lime plaster, a red portion and a black portion of the same plastic banner, ashlar limestone, and glass.

In order to perform the test, a small software was developed combining AutoCAD’s Autolisp and Visual basic, to extract the value of the reflectance of points located in a radius of 3cm from a point selected by the operator, and to perform and draw the corresponding histogram. For this data extraction we used mathematical “balls”,

This has enabled to quickly get a large number of data to analyze, a total of 225 balls, 25 for each material 75 corresponding to the three transitional areas (Fig. 6).

We grouped the graphs of each material in order to visualize the correspondence or concordance between them. The result was conclusive: all the balls of the same material form a curve show almost identical curves (Fig. 7) which confirms the hypothesis that all elements of a type of surface can be represented by a curve feature, determined by the reflectance readings of the laser scanner

As a significant fact, it should be noted that the curve of the black banner stands practically on the far left of the graph, precisely on the lower reflectance values. This is due, undoubtedly, to the high energy absorption capacity that the black plastic has. Indeed, pure black is that color that does not reflect any of the light that. Conversely, the red portion of the same flag, despite being the same material, presents a curve with much higher energy levels.

We analyzed, also, to observe their behavior, three transitional areas, i.e. the areas of contact between two different materials. Here we have generated 25 balls of each of the focus areas, the central point being the point of contact between two materials: one between the stucco and the stone masonry; a second one between the stucco and black banner; and the last between stucco and the red flag (being the stucco a very stable and well characterized material and histogram).

The graphs obtained (Fig. 8) surprisingly led to a double curve that can be identified as the sum of the curves of the two materials (or the transition from the one to the other) which opens the possibility of analysis and identification of areas of contact.

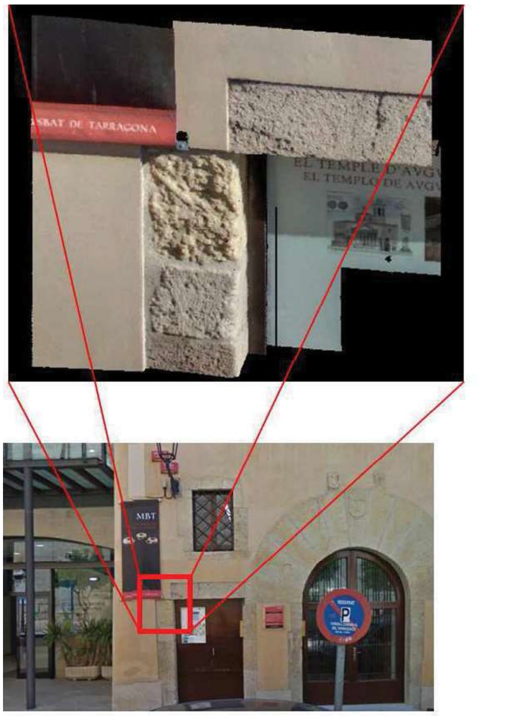

Figure 6. Study area from 2nd experimentation.

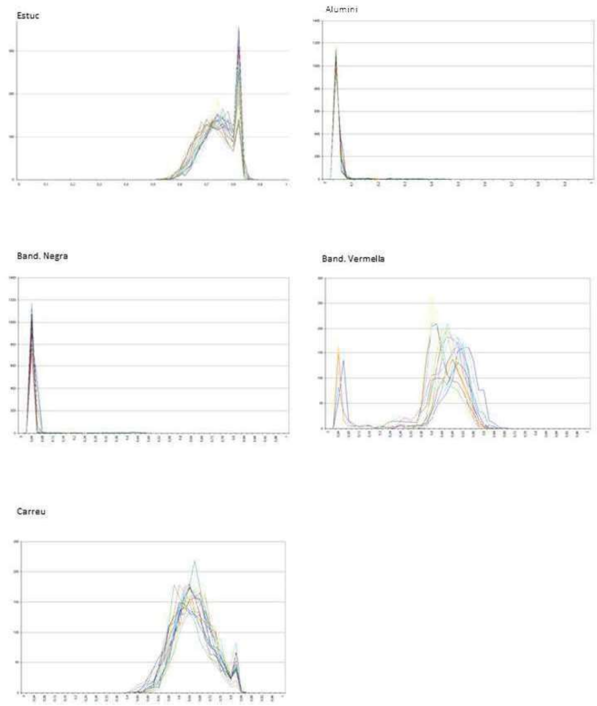

Figure 7. Histogram the materials of 2nd experimentation.

6 CONCLUSION AND FINAL DISCUSSION

In conclusion, we can now ascertain that the statistical depiction of a ball of the reflectance values given by the laser scanner can be used to typologically identify segments of a scanned area. This method can be used to differentiate materials, colors (as in painting, finishing, etc.) and other factors, such as moisture (Fig. 5).

We still need to determine the effects of the distance and the reading angle, and the variability that certain factors such as moisture or paint and coloring can give. This involves the design and implementation of a third experimental phase which contemplates these factors --and which will define as well the behavior of the transition areas between different materials.

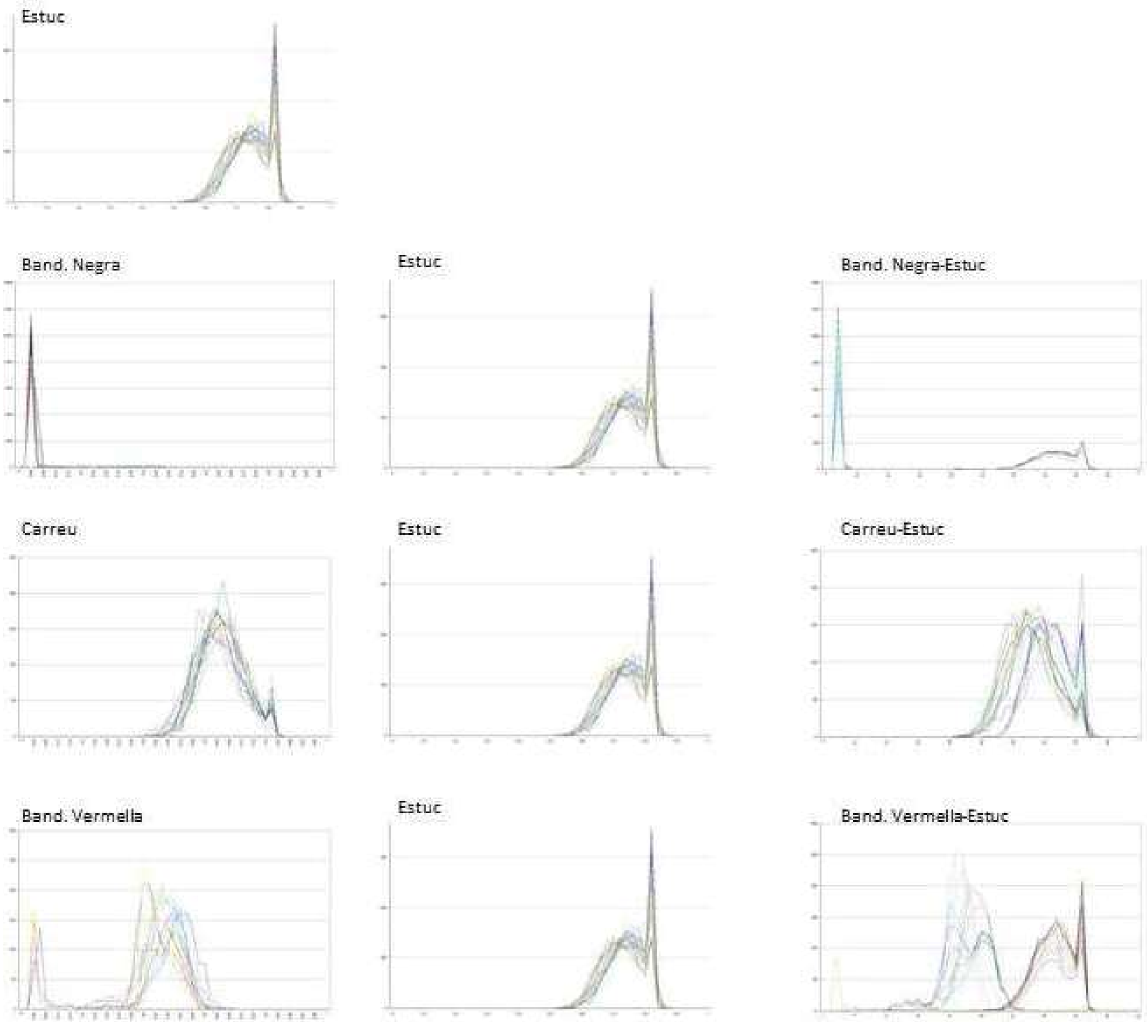

Figure 8. Histogram from the transition area used in the second experimentation.

If the results of this last experimental phase are consistent with those obtained so far, we can create an algorithm that enables automatic reading and discrimination of scanned areas, and propose a mapping of the surfaces where different typological elements have been identified and individualized.

If so we would be witnessing the birth of an Computer-assisted Archeology of Architecture, and a greater utility would be given to laser scanner point clouds , beyond the purely geometric.

ACKNOWLEDGMENTS

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Index of Authors

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Furthermore, different communities' scales (local, regional, national or even worldwide) and authenticity interpretation raise different questions and approaches, and therefore different solutions that are worthily to study, to compare and to experience.

The sustainability approach is again covered, highlighting the importance of the commitment between heritage preservation and technical requirements related to its occupancy and use, such as energy efficiency or materials recovery.

Inclusivity is also an important aspect to be discussed as public historic sites and buildings need to be adapted to receive different kind of visitors (children, elderly or handicapped persons) and to establish an adequacy with the perceiving of the physical environment and information contents.

As a Special Chapter, Earthen Buildings are brought into a particular approach highlighting the complexity of their preservation, maintenance and rehabilitation. Earthen buildings techniques are in many cases of a great importance for local economies and access to housing.

The Editors

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