Integration of geomatic techniques for the analysis and geolocation of graphic forms of the Filocalian letter in the Elogia Martyrum by Pope Damasus(366-384)

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Abstract

The purpose of this paper is to retracea research carried out concerninggeometric-dimensional surveyson the epigraphic production of the *elogia martyrum* composed by Pope Damasus.
The photographic survey methods initially employed will be described along with the latest analyses made, which include the use of several features related to the field of geomatics.
Terrainsurveyshave been planned and carried out to examine in depth the graphic forms of marble writing, in which every single letter engraved has been analysed with submillimetric tolerances.
Lastly, attention is focused on the use of some elaboration features of the Digital Terrain Modelling (DTM), such as the recreation of altimetry classes and the visualisation of shadows to obtain additional information relevant to the terrain analysis of stone plates and engravings.

Keywords

Epigraphy, Geomatics, Digital survey, GIS, Photogrammetry

1.Introduction

In the present paper attention is focused on the research work made in 2002[1], whose aim was the definition of a survey procedure, using an analog two-

[1]A research carried out in my bachelor dissertation in Epigraphy and Christian Antiquities entitled "Formegrafiche e TecnicaesecutivanegliElogiaMartyrumdi Papa Damaso" (supervised by Prof. C.Carletti, University of Bari).

dimensional acquisition method and ahybrid output (analog-digital) to analyse the technique used for epigraphic products.
The study focuses on some samples of the epigraphic production of the Elogia Martyrum by Pope Damasus(366-384) commissioned to Furius Dionysius Filocalus, his contemporary and well-known calligrapher, who realised the engravings on marble.[2]
The steps followed during the research process will be herein briefly explained, along with the methodology that allowed the identification of shape variations in the technique usedby means of a two-dimensional comparing process.
Provided that techniques, equipment and expertise in this field have improved over the course of ten years, I had the highly interesting opportunity of re-elaborating the data previously collected with technologically advanced and integrated analysing methods, typical of the field of geomatics[3].
Furthermore, I tested a fully-digital survey procedure with very high resolution, providinga better reading definition and capturing three-dimensional data of the engravings, in order to analyse them with GIS survey equipment and obtain morphological features to better understand the formalization dynamics in the technique used.

2. Primary research

For the preliminary study performed with analog methods[4], Damasian epigrams have been chosen due to the fact that this kind of production has beenengraved over a short period of time[5], revealing extremely interesting morphological features related to various aspects of the historical and cultural context in which it has been realised.
The purpose of this research was to determine if the eminent "ordinator"[6]Filocalus experienced an evolutionary process in the realization of his epigraphic production, which was performed with the same high and refined quality of his graphic work, to understand how did his activity of

[2]Ferrua 1942; Carletti 2000; Carletti 2008, translation and comment by A. Aste2014.

[3]Geomatics involves all application such as Topography, Photogrammetry and Cartography, generally managed in a geographic information system (GIS).

[4]Using film cameras, processing and printing in darkroom

[5] According to Ferrua, all the epigrams engraved by Furius Dionysius Filocalus date back to 370-380 Cf. Carletti 2000 p. 351

[6]As shown in the literature, it seems likely that it was his first experience as lapicide. Several hypotheses have been formulated on the real profession of Filocalus, known as talented and cultured artist, especially referring to the frontispiece of the Chronographusanni 354, where N. Gray e A. Petrucci have opposite opinions. Cf. Gray1956, p5; Petrucci 1973, p.39

lapicide[7]influenced the ‘standards’ of the authentic art of Filocalus, as Ferrua identifies them.[8]
Based on their state of conservation, eighteeninscriptions have been examined.[9] The research work started with an experimental stage of image acquisition, in which different kinds of film and lighting techniques have been tested, using the most appropriate equipment and photographic objectives to obtain the morphological data needed to compare graphic forms.
The photography methods used were the ones available at the time, namelyhigh quality objective lenses, using a slow speed and low contrast film andsidelightingto better highlight the shadows produced by the engraving.
In this manner I could proceed with the final photographic survey and move on to the rendering phase, dimensioning scanned analog pictures and removing margins from each letter engraved using a standard contrast filter.
This procedure enabled the editing of catalogue entries, through a detailed analysis of the characters’engravings, analysing every single letter and assembling an alphabet for every stone plate, composed by the characters selected from each epigraph.

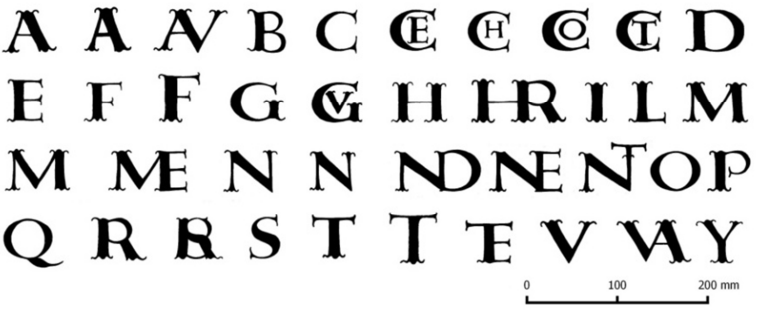

Fig. 1 *Alphabet extract epigraph dedicated to the martyr Eutychius (ED21) affixed at the inner wall of the nave of San Sebastiano church in Rome.*

A thorough analysis based on sight comparison showed uniformity in the technique used, yet from the few samples examined it is not possible to define a time sequence[10.] Nevertheless, a gradual change can be observed in the style of Filocalus as we move away from the epicentre of the cemetery of Callixtus. Given that the inscriptions found outside thistopographical area seem to

[7]The classification of stone plates according to Ferrua is divided into Filocalian and semi filocalian.Cfr. Ferrua 1942, pp. 21-35. D. Nuzzo 2014, pp.645-648.

[8]Ferrua, pp.46-49

[9]Ferrua 1942. ED 3, 7,8,16,17,18,181,19,21,24,25,27,28,34,35,37,47, 5.

[10] According to Ferrua (1942), all the samples dating back to 370-380 are considered authentic Filocalian works, including the epigram dedicated to the martyrs in S. Callisto. Cf. Carletti 2000, p.351

depart from the rigid Filocalian scheme. I hypothesised the existence of a main workshop,probably set up in the environs of the catacombs of Callixtus, where Filocalus was directly involved, employing the result of a tenacious practice[11] which would lead him, as Ferrua states, to adjust his alphabet fromparchment to marble[12].On these terms, considering the extended topographical area on which Damasus conceived his project, I considered the existence of some other workshops positioned in the area pertaining to the cemeteries involved, where craftsmen, conveniently trained by the master and with the best understanding of the technique, showed some autonomy over time and diverged from the style of Filocalus, changing models and layouts.

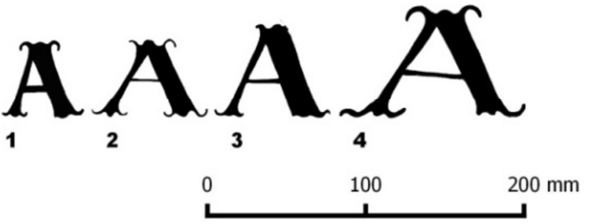

Fig. 2 *Letter "A" extracted from the epigraph eulogy dedicated to: 1 - martyr Eutychius (ED21), 2 - the Saints and Popes buried in Callisto (ED16), 3 - Saints Peter and Marcellinus (ED28). 4 - Saint Agnes (ED37)*

3. Development of the elaboration with geomatic procedures

The technology available to realise microgeodetic surveys and metric analyses has considerably improvedover the last ten years, especially with regard to the lower cost of the equipment and the accessibility of the elaboration process offered by both commercial and open source software products.
This premises allowed a substantial improvement in the quality of the results, from the point of view of both the reduction of measuring tolerances and the significant increase in geometric and radiometric resolution.[13]
For this reason I had the stimulating opportunity of testing the results of my previous research, using upgraded analysis systems and capitalising on the means that the field of geomatics offers.

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[11] The comparison involving all the epigraphs examined highlighted several elements on the plates that might be considered as negligence of the lapicide , but can also be interpreted as attempts aimed at perfecting the technique, such as in the engraving about "Prosciugamento del cimiteroVaticano" (ED 3; ICUR II, 4098; Carletti 2008, n. 155).

[12]Ferrua, 1942, p.47

[13] Reading capabilities on very small geometric elements (pixel dimension on the object even lower than 1/10 mm) are amplified by a wide tonal range, which can be processed using the RGB visible band, the NIR (Near Infrared) and the UV band.

In particular,the possibilities of photogrammetry and GIS analysis have been explored, thanks to their now seemingly user-friendly features, which allowed the creation of three-dimensional models with high geometric resolution and very in-depth terrain surveys, providing new insights in the study of epigraphic lettering and surface analysis.

3.1 GIS and space analysis for the detection of graphic forms variations

The ambitious project of Pope Damasus covers an area of land so extended, considering theposition of the cemeteries involved, that it can be considered as an authentic urban planning project[14.]
In this respect, GIS procedures -typical of territorial analyses and normally aimed at urban and large area planning- have been applied to examine any potential connection between the technique used for the epigraphs and their position.
Furthermore, considering the surface of a stone plate as a land area and its features as soil morphological variations, GIS advanced analyses may provide a considerable asset for the examination.
I have therefore set up a georeferenced database in a GIS environment, editing all the data collected to obtain a GIS-readable format[15.]
The catacombs and the epigraphs concerned have been located using generalcartographic information, drawn upon the usual sources, including the digital mapping by the Institute of Military Geography (IGM) on a nominal scale of 1:25,000, the Regional Technical Map (CTR) of the Lazio Regionon scale 1:10,000 and orthophotographs from various periods with different geometric and radiometric features. The general maps available allowed the planimetry of a small number of catacomb complexes[16]to be geo-referenced, in order to connect the position of the cemetery to the greater or lesser presence of stone plates.It should be noted that a rigorous examination of thespatial distribution of the epigraphs would require a GISgeometric editing of the existing plans and an accurate positioning with GNSS methodologies[17.]

[14]Defined today as “detailed plan”

[15]The data in each catalog entry has been tabulated, each image used has been georeferenced on an official cartographic base, all the vector data have been converted from the CAD format into the SHP format.

[16]For the southern areacfr. Spera 1999.

[17] GNSS Global Navigation Satellite System. This acronym includes satellite positioning methodologies (e.g. GPS, GLONASS, GALILEO etc.)

A detailed placement of such fixed points[18] would allow the improvement of many considerable surveys of the underground tunnels' routes carried out up to now.

The most substantial phase consisted in the planning of the Database, which entailed distinctive evaluations on the choice of data structure, field/attribute contentand geometric primitives data capture (points, lines, areas, etc.). Accordingly, the commonly named logical model was built to defineattributes and correlation fields[19,] to be used for effective analyses in view of the research.The following scheme shows briefly the elements used for the structure of the logical model:

1. A database with punctual geometry[20]to localise each catacomb, tabulating specific attributeswith archaeological and historicalfeatures. A Catacomb ID field is the primary key to build connections with the connected DB.
2. A database with punctual geometry for the positioning of the epigraphic stone plates within the planimetry of the catacomb, with attributes describing general characteristic on the device[21]and possibly a link to textual interpretation. An Epigraph ID field is the primary key for the connection between each epigraph and the corresponding letters engraved, using the codification realized for the research in 2002.
3. A database with areal geometry describing each letter using attributes aimed at morphogeometric features.

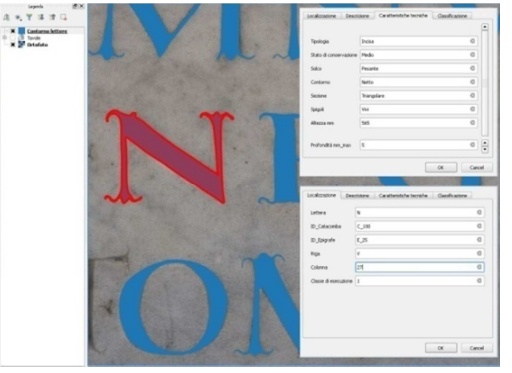

Fig. 3 *Attribute extraction geodatabase letters.*

[18]For example, setting skylights on the overhead surface allows tunnels to be connected to each other.

[19] Di Stefano Manzella, 1987 p.147. With reference to section 13.6.6.

[20]After an exact georeferentiation and geometric editing on the obtained planimetries have been performed, geometric data are converted into aerial data.

[21] In this case the data included in the catalogue entries have been included.

An automatic vectorisation with CAD tools[22] has been realised to avoid altering the data related to the perimeter of the letters'marksin the manual digitisation of raster images[23.]
In this way,the extraction of vector outlines has been used to examine each character in terms of geometric- dimensional evaluation, the extraction of vector outlines has been performed with procedures that marked the barycentreand pixel outlines in contrast variations, obtaining vector files for each letter. These files have been consequently georeferenced with their position on each corresponding plate, so that every digitised object could populate the database.
Particular attention has been paid to the evaluation of "weights" both in the database concerning the stone plates and the one with the data relative to the letters, to show the "pureness" of the filocalian style.
The values selected,with a range from 1 to 5, which can be found in the catalogue entries included in the 2002 research work, provided the basis for the preparation of spatial analysis. The geolocalisation of the pattern in some characters' variations has been examined by means of a GIS query environment, providing a solid framework for the evaluation of formal changes in the lapidary marks in a georeferenced topographical context.

3.2 Survey and creation of a three-dimensional digital model

The tests previously described have confirmed that starting a surveying process set to obtain a submillimetric three-dimensional analysis will allow the large potential of GIS environment analyses to be capitalized on.
On the basis of experimentations carried out with current three-dimensional surveying systems, a three-dimensional model of the epigraph with very high geometric resolution will be created using only photogrammetric and fully digital methods.
The experience gained over the years on territorial analyses aimed at solving planning problems and environmental protection issues, allowed specific features of the GIS environment to be tested, including the study of soil morphology[24]designed for shape calculations, features and variations analysis related to anthropic and natural intervention.
These processes have been therefore used to examine the surface of an inscription[25], whose survey was intended specifically toobtain data,

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[22]An effective vectorisation procedure, developed for cartographic purposes, is included in the Bentley Descartes V8 application developed for MicroStations.

[23] Those obtained with contrast filter on digitised images.

[24]Frequently used in pedology and geology.

[25] In my research, these procedures are employed on marble, but their utility for other kinds of surface is not excluded.

morphometric information and statistical evaluations from its structure, according to the digital evaluation model (DEM).
The test stand for an initial review of the process has been the epigraph dedicated to the Martyr Eutychius affixed at the inner wall of the nave of San Sebastiano church in Rome, whose position provides easy access and enough space for data recording procedures.
The widespread use of algorithms typical of Computer Vision (CV) put photogrammetry into a new phase in which initial frame orientation procedures have been simplified.
The whole process may appear as a simple one,but actually great expertise is required to obtain reliable results in terms of measurements and go beyond the mere visualisation of a texturized model[26].
The sequence of operation is essentially the same used in photogrammetry with the facilitation based solely on numerical operations, without any need for stereoscopic vision of the operator, capitalising oneffective image matching[27]procedures and fast triangulation algorithms with Bundle Block Adjustment[28].
Knowing that a high resolution camera and lenses with low radial distortion are fundamental to achieve reliable geometric results, in the case study every take has been realised with a Nikon D800 36MP camera and a fixed focal lens of 55mm. In particular, the lens used is the same employed in the previous research work – it was then used on a film camera body[29]–which in any case has been tested ona digital sensor with pixel size equal to 5 µm.
Particular attention has been paid to lighting techniques; the procedures performed diverged widely from the classic approach used for epigraphs photographic images.An oblique lighting would have accentuated the engraved characters through sharp shadows; an evenly diffused lighting provided instead the optimisation of pixel resolution and facilitated the collimation of homologous points.
An electronic ring flash[30] has been used to obtain a perfectly stable exposure, with no traceof shadows. Approximately 100 images were taken, including 75 on very large-scale (GSD[31] = 0.05 mm) and 25 on large scale (GSD = 0.2

[26]Nowadays it is commonly used for three-dimensional visualizations.

[27] Automatic image correlation

[28]Bundle Block Adjustment methodologies have been developed in the 70s for industrial use in the fields of aerial and land photogrammetry; it allows a steady orientation of the camera

[29.] An analog Nikon FM2 camera.

[30]Electronic flashes equipped with emitting lights arranged in a circle facing the frontal lens of the objective.

[31] GSD = Ground Sampling Distance: it corresponds to the pixel dimension projected on the concerning and provides an evaluation of potential geometric resolution.

mm), which have been consequently edited to switch from the NEF[32]format to a more standard TIF.
Capturing GCPs[33]was an essential part of the process, as they have been surveyed using strictly three-dimensional coordinates, in this case belonging to the local reference System, to obtain a tabulation of the coordinates X, Y and Z, required for the photogrammetric absolute orientation phase[34].
For the following rendering phase, performed at a different time in a laboratory provided with medium-high performance calculation systems[35], photogrammetricmodels[36] have been set up with the following methods:

1. Interior orientation: defining calibration parameters for the camera (previously adjusted at the laboratory);
2. Relative orientation: recreating the orientation parameters among the images shot (also called alignment);
3. Absolute orientation: collimation of GCPs for every frame, realizing the bundle block adjustment and orienting the 3D model into a set reference system;
4. Providing cloud points[37],DEM e DSM[38] digital models, construction of Meshes which have been texturised with the captured pixels.
5. Exporting the results and bringing the object on a projection plane with an orthographic projection.

Pictures taken at a medium distance provided an orthoprojection with GSDs of 0,5 mm, which can be used for a general analysis of the epigraph, whereas shots taken at a short distance allowed the reading of geometric elements with tolerances of less than 1/10mm.
Once this preparatory phase has been completed, the next step was the creation of a high resolution digital terrain model to elaborate soil digital

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[32] An uncompressed format containing all the shooting radiometric layers.

[33]GCP=Ground Control Point: topographic landmarks captured with different measure procedures, including GNSS systems and topographic total stations.

[34]In this case, landmark surveys had been already performed in the previous research; this time they have been used after a direct measurement control.

[35]ProSIT. Geomatics Laboratory of the Department of Architecture, Design and Urban planning based in Alghero, part of the University of Sassari. www.prosit.uniss.it

[36]Nowadays many different software products are usedfor these procedures: from the most popularAgisoftPhotoscan (which I tested out), toPhotoModeler Scanner, from the professional ERDAS Image LPS, to Menci APS and the Open Source softwareMicMacdeveloped from the French IGN.

[37]Point cloud: combination of 3-D coordinates relative to the points of the object's morphology, measured in automatic mode. It ranges from tens of thousands to tens of millions of points, according to geometric resolution and acquired extension.

[38]Unlike DEM, which only include elevation points (height), DSM shape the scanned surface with triangular surfaces built on the point collected

models[39].In summary, analysis procedures belonging to the specialised fields of cartography, pedology and geology have been applied on epigraphic products, testing how investigation options can be extended.
Some interesting possibilities have been found applying the following procedures:

1. Sections comparison. This instrument is normally used for infrastructure designs, in particular hydraulic systems, to examine the slope of the concerning ground. In this case the procedure has revealed itself useful to examine every letter engraved, surveying every section and obtaining a comparison diagram which "highlight the rules determining the gradual widening and narrowing of the marks according to the dimension of each letter." [40]

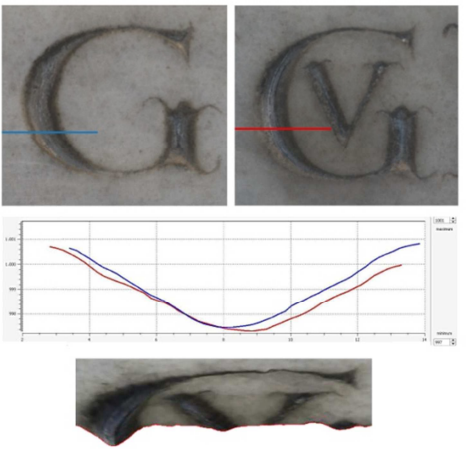

Fig. 4 *Sections comparison and three-dimensional visualization of the section line*

2. Shadow simulation. This function is often used to study shadows casted by building volumes and adjust solar energy sensors. In this case, the engravings on each plate have been examined according to light source, building one or more shadow representation related to the virtual light source positioning. This procedure might prove that Damasus included an emphatic and evocative aspect in the project for his Elogia, merging lighting direction and the engraving's depth.
3. Contour lines and altimetry mapping. These instruments are commonly used in cartography to represent terrain variations and height differences. It has beenused for the altimetry mapping of

[39]GIS QGIS software products with the GRASS extension have been used to analyse 3-D morphological features

[44]Di Stefano Manzella, 1987 pp. 147-148

plates in the sections that are not engraved, to quantify the surface erosion and calculate the difference in volume, in case of restoration works.

4. Flooding algorithm. Very common in environmental surveys, it is used to recreateflooding catchment areas. The virtual filling of every single letter's engraving allows the automatic extraction of a raster file (without an operator performing photo interpretation), so to define the borders of each stone plate at the edge of the engravings with details and accuracy that are directly proportional tothe pixel resolution of the calculated DEM.

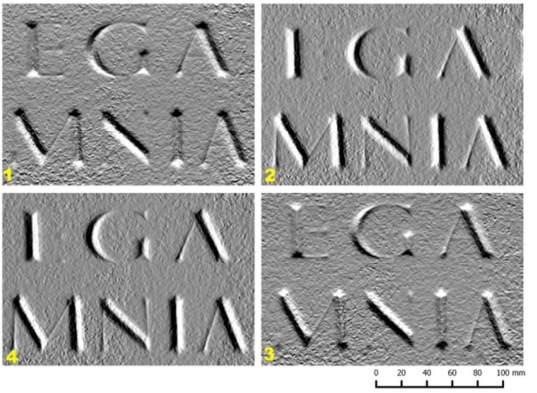

Fig. 5 S*hadow simulation(source of light coming from 0° - 90° - 180° - 270°)*

Fig. 6 *Contour lines and altimetry mapping*

4. Concluding remarks

The complex procedures here described, based on a research work carried out with completely outdated technologies, provides many valuable considerations. First and foremost, the need for a multidisciplinary involvement that should merge historical and technical knowledge. The so called 'low cost' surveying processes, normally originated from CV processes (Structure from Motion SfM), are now widely employed, but the experiments conducted showed that their ease of use leads to extremely simplified processes, which may have valid visual renderings to the detriment of geometrical results.
The photogrammetric process, still considered a complex one due to the connection ofseveral serial runs, can achieve high performances only if performed in a strict manner form the planning phase to the three-dimensional model elaboration, and, to my mind, it should not be considered as the finishing line, but rather asa starting point.

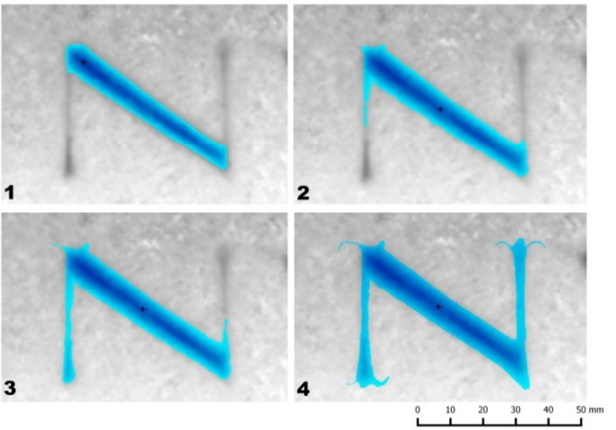

Fig. 7.*Flooding algorithm.*

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