New Technologies Applied to Artefacts: Seeking the Representation of a Column's Capital

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Abstract. Since 1996, the CARPA Research Team has been working on the assessment of how new tools, applicable to their speciality, can be used in an innovative way to capture and process information in the fields of archaeology and heritage. This paper presents a methodology for creating a graphic representation of an artefact once the register and documentation of the object have been obtained. The location of the artefact was referenced from this point and the cartography of its surroundings obtained. The first step was to apply photogrammetric methodologies to obtain the metric definition, and afterwards, by means of techniques such as 3D scanning to customise software, and other products. The paper will also discuss other proposed means of dissemination. It questions how easy it is nowadays to obtain data and demonstrates why interpretation needs to be integrated in the progress.

1. Introduction

Archaeology is described as a science surrounded by adventure. Some findings have been, as has often been told, fortuitous, the fruit of chance. Others, on the contrary, have been the result of previous, long and intensive work. Very often, even the originality of the findings is questioned. This science, taking into account facts which have their roots in the past, is susceptible to multiple interpretations, and, supported by processes of documentation and register, creates history.

This work aims to be a reflection of all this, and, in particular, of the simplicity of data gathering, and the simplicity of interpreting such data in different ways which may even alter the processes and the results. Throughout the work, papers have been elaborated by CARPA Research Team, which has conducted its research activity in the laboratories of the Higher Technical School of Engineering and Surveying of the Polytechnic University of Madrid (UPM).

Through engineering technologies, the CARPA Laboratory works with data acquisition produced by different teams using topographic, photogrammetric and geodesic methods, in order to obtain 2D and 3D representations of objects, buildings and surfaces. Our speciality also extends to design techniques and associated technologies, such as Geographic Information Systems (GIS) and Remote Sensing.

The results presented in this paper are supported by a 2D and 3D representation of a capital, with an internal precision in details of 2,5 mm. They have been obtained by initially using photogrammetric techniques, and, then, afterwards employing the 3D-Scanner methodology. This data is completed with traditional distribution models.

Our "*History of a Capital through New Technologies*", starts with the description of the discovery and the process of documentation "in situ", and continues to describe the works carried out in the laboratory and concludes with new alternatives. Archaeology is defined as the past that becomes the future. Our proposal is that in that future what already existed is not forgotten, and our advice is that the archaeologist must be the one who must constantly value and question the research policies proposed and the results obtained.

2. Description of the Finding

The story begins in the summer of 1997 in Recópolis, at 100 km from Madrid. A Visigoth city, excavated by Dr. Lauro Olmo, is located there and has become an Archaeological Park supported by the Community of Castile-La Mancha.

This Visigoth city is located on the Cerro de la Oliva hill, within the municipal area of Zorita de los Canes, on the southern border of the province of Guadalajara. Zorita de los Canes is a small village situated in La Alcarria Baja. The Hill is bordered from North to South by an ancient pathway, and is surrounded by the Tagus River. A palace and a basilica integrate the urban structure of the site, which includes buildings of 100 metres in length with a width of 10 metres, and structures of more than one floor. Dr. Lauro Olmo suggested that we collaborate on the multidisciplinary works he was carrying out on the site by providing cartographic support of the environment and the site itself. Our contribution was to elaborate a general cartography at scale 1:500.

We started by establishing a precision network of the national geodesic coordinate system. The link to the official network was divided into two parts: plannimetry and altimetry. The aim was to provide coordinates for the points in the work area. The plannimetric link was established using the classical methodology combined with GPS techniques. Four geodesic vertices, expertly distributed around the area of the object of excavation, were chosen, and the network was observed through triangulation, trilateration and GPS observations, with a rapid static positioning.

10.938 points were radiated from the vertices of the basic network and the secondary network. This significant amount of points was originated due to the archaeological requirement to represent the morphology of the area, providing detail of all types of rock outcrops and any indication of slightly ordered or lined rocks, mainly considering that the hill is a virtually untouched site and that the cartography would be a support throughout the entire documentation process.

Data was recorded in the field on a magnetic card incorporated with the total position. Once the fieldwork was finalised, data was treated in the office. The computer programme -Microstation- was used to draw the maps and the contouring was carried out using one of its applications -InRail-. Once the editing and drawing of the maps were finished, they were graphically represented, and revised in order to check the result of the work and make any necessary amendments.

Once this first phase was finished, during a subsequent campaign, we continued updating topographic tasks, using the necessary field data to elaborate the cartography of the excavation area at scale 1:100. Taking a break during the inventory, we went to the Tagus River to complete the panoramic data. By chance, an archaeologist who was accompanying us found the capital (Fig. 1) in a corner of the river basin. We had been scouring the area for more than four years, and the archaeology team for even longer. However, what surprised everyone was the fact that it was the drought and the closing of the dam which caused the descent of the caudal, revealing such a special piece.

The dimensions of the capital are 39 cm by 26 cm by 24 cm. It is of Corinthian style and is surrounded by figures of acanthus leaves. The geological study determined that the material is secondary limestone (calcrete) of a chemical precipitation origin.

The first question posed was to confirm whether the capital had originated from the archaeological site or had been transported there by water from a different location. For the analysis of this problem, and as a support for further studies, the coordinates of the place where the capital had been found were determined, by georeferencing its position with a non-prism TC 705 station, and carrying out superfluous observations from the principal network.

Fig. 1. Capital in the place it was found.

3. Metric Description

With the consent of the archaeological team and the authorities involved, the capital was transferred to the CARPA laboratory of the Higher Technical School of Engineering in Surveying of the Polytechnic University of Madrid in order to proceed to its metric analysis.

3.1 Photogrammetry

The photogrammetric uplifting of the capital was carried out in order to study the possibilities of using photogrammetric methods and digital modelling techniques in archaeological pieces, giving the sites and archaeological works a precision appropriate to these techniques.

D. Javier del Amo, at that time, a student of Technical Engineering in Surveying, elaborated his final year project with the work "*Archaeological Surveying. Elaboration of a 3D digital model of a capital using photogrammetric methods*". D Francisco J. García Lázaro, a lecturer at the Higher Technical School of Engineering in Surveying of the Polytechnic University of Madrid (UPM) played a special part in the tutoring of the work.

The specific aims of this project were the securing of a three-dimensional digital model of the capital, applying photogrammetric methods for near-by objects, with a final precision on the coordinates of the object of 2,5 mm, securing a methodology that was precise and feasible to be used in the field, and easy to transport and apply. This digital model could be incorporated in the reconstruction of the archaeological environment, in the reconstruction of the piece in the eventuality that it could be in bad condition, in the acquisition of profile and transverse sections, and could be integrated in multimedia applications with different finishing and visualisation sequences.

The physical features of the capital confronted us with possibly one of the more difficult cases, since it was an artificial object of irregular shape, and very deteriorated, which complicated the definition of details and the stereoscopic display of its surface, due to the material used in its production.

The place chosen for the observation of the support points and the photographing was a classroom in the School of Engineering in Surveying, with both good natural and artificial light, and wide enough to be able to locate the total stations at a distance that was double the minimal focus, in order to carry out the reciprocal collimation between them. The possible vibrations of the building structure that could affect the positional stability of the support points were considered insignificant throughout the observations.

Two sorts of points were observed: support points and auxiliary points. In the case of the support points, spherical signals of 4 mm diameter were used, which permitted good aiming from any incidence angle of the line of vision. The auxiliary points were materialised using round adhesive targets, being very careful with the angles which could affect the lines of vision.

The points of support were located on a metallic support structure, in the shape of an inverted table of 50 cm by 60 cm,

with legs approximately 40 cm long. The support points were distributed, placing three of them on each leg at three different heights: one above the floor, another one at about 20 cm and a third one on the upper part of the leg; and 4 more, one in each lateral of the structure, in its middle. These points of support were used for the calibration of the photograms and throughout their orientation process. In total, 16 points of support were placed on the support structure.
The auxiliary points were placed behind the stations on the floor and at different heights on the room walls to cover a wide range of zenithal readings. In total, 13 signals were available.
In order to conduct the observations, three TC 1610 total stations by Leica were used with stationing equipment and rigid STARS. The observations were simultaneously carried out using three operators, thereby, reducing the observation times and the problems derived from them.
The observation method was used to carry out the reciprocal collimation between two of the stations, and, from the third, readings of the support points, auxiliary points and the pattern rule were taken. The reciprocal collimation between the stations was undertaken to give a greater consistency to the network of points, since it permitted the introduction of observation equations between the points of the stations. The observation was initiated taking a distant reference and then the support points and auxiliary points were observed, producing horizontal and vertical readings within a direct circle and an inverse circle.
For the calculation of the support points, programmes Topmodel (which adjusts the relative position of the range of theodolite lines of vision with regard to another, based on the coplanity condition between each two lines of vision to a similar point and the base formed by the theodolites), Hel3d (allows us to carry out spatial similarity transformations reducing the files to just one system of coordinates), and Excel 4.0 (for the matrix calculations) were used. The first two have been developed by Professor Francisco García Lázaro, in addition to the programmes – coplana, resectio and DLT – which were used for the photogrammetric adjustment.
In the calculation process, first of all, the analytical relative orientation of the theodolite stations was carried out in order to obtain the coordinates of the common points observed from the stations, but with an arbitrary scale and orientation. The four clouds of independent points with different scales and orientations were distributed in only one system of reference through spatial similarity transformations.
The model was scaled using the coordinates marked on the pattern ruler. In order to level the system, a transformation was undertaken. Thus, the coordinates of the 14 support points were obtained.
For the photogrammetric process of the project, without knowing the internal parameters, a nonmetric reflex camera was used. This sort of camera has the advantage of being cheaper and easier to use, besides using cheaper film, which is easier to process. Since they are not calibrated, the determination of the parameters must be carried out for each take, which implies an increase in workload during the process. The camera used was a Yashica of focal dimensions 35–50–60–70 mm, which uses negatives of 24 x 36 mm, a manual diaphragm and possible apertures 3,5–5,6–8–11–16–22. An automatic flash, two spotlights and a shooter cable were used as auxiliary equipment.
The experience and study of other similar works recommended the use of focal f=35 mm and nº f=22. It was calculated that the base of the takes had to be 30 cm and the distance had to be 90 cm. Photographs were taken of each side of the capital, so that there were a couple of each, repeating the photographs to be able to have two types showing each face and thus, allowing us to choose the best one. Once the rolls of film were developed and paper copies were made, the photographs for the work were selected. In order to work with the digital restitutor, the negatives were scanned using the AGFA Horizon Plus scanner.
The photogrammetric process of calibration and orientation of two sets included the following phases:

- Previous measurement to determine the parameters of internal orientation of each photogram.
- Determination of the parameters of the internal orientation of the camera.
- Internal orientation of each camera.
- Relative orientation of each pair of photographs.
- Absolute orientation of each pair of photographs.
- Verification of the adjustment.

The restitution of the capital was undertaken using the Microstation environment, which supports the digital restitutor. The digital model was transformed with points and lines obtained through the stereoscopic display of the epipolar images obtained. In each model, as many points as required to obtain a good distribution for the triangulation of the digital model, were obtained. The edges and well defined details were restituted through lines, and the uniform areas or areas with a lower level of detail were restituted by points (Fig. 2). The cloud of points obtained was triangulated using the Intergraph modelling programme.
From the metric point of view, the modelling process can be considered finished following the generation of the net of triangles with which the surface of the object is presented through a set of finite surface elements (the triangles). However, from the point of view of the representation, the

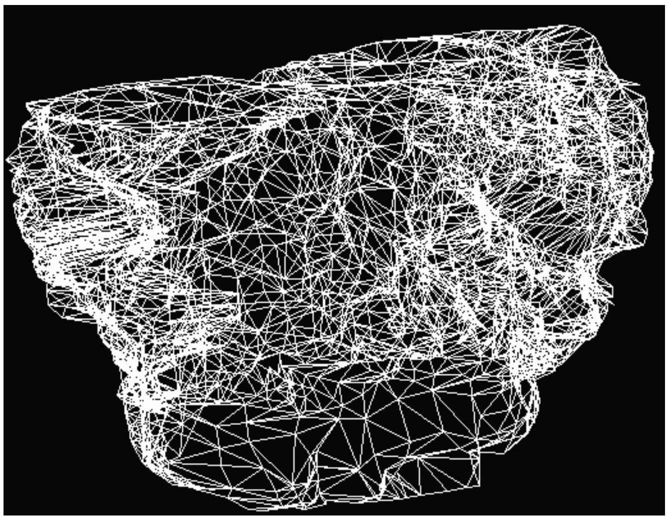

Fig. 2. Triangulation of the model.

results can be improved by applying textures to the superficial elements which are similar to those of the object's constitutive material, by simulating lights of different effects and obtaining shadowy representations of the object from different angles of view, which include stereoscopic images and in motion animations.

Although this exceeded the objectives of the project, some of these representations were made. The assignation of the material was carried out by defining a texture obtained through scanning a colour photograph of the capital. This texture was applied to the finite surface elements by which it is represented. Afterwards, an animation of twenty images of the capital, constructed around it using stereoscopic simulation was developed.

3.2 Three-Dimensional Scanning

Recently, new systems for data gathering that use 3D scanning techniques have appeared on the market. Using these, data can be collected in a continuous way, obviating the selection of points on the field and thus avoiding the remaining subjectivity in a surveying uplifting. Data gathering is automated in the field, and the selection of information is carried out in the laboratory. Leica kindly put the equipment Cyrax 2500 at our disposal for metric analyses in surveying, engineering and construction applications.

Our experience with the TC 305 Leica station (for direct measurement without a prism) permitted working with ranges of discrete points, interconnected through minimum quadratic adjustments. The Cyrax equipment enabled the continuation of this line of research with continuous sequences of points, and, therefore, we decided to apply 3D laser technology with the Cyrax 2500 from the Leica Geosystem to archaeological pieces, in particular, to the capital – the object of our research (Fig. 3).

The methodological process involved situating the scanner over a tripod and connecting it to a laptop. Once it was oriented towards the object of uplifting, the area to be uplifted was selected through a rectangle on the screen, and data gathering begun. The equipment only needs fifteen minutes to complete the acquisition of the perspective range from the station, permitting in real time the obtainment of points clouds and the net of triangles.

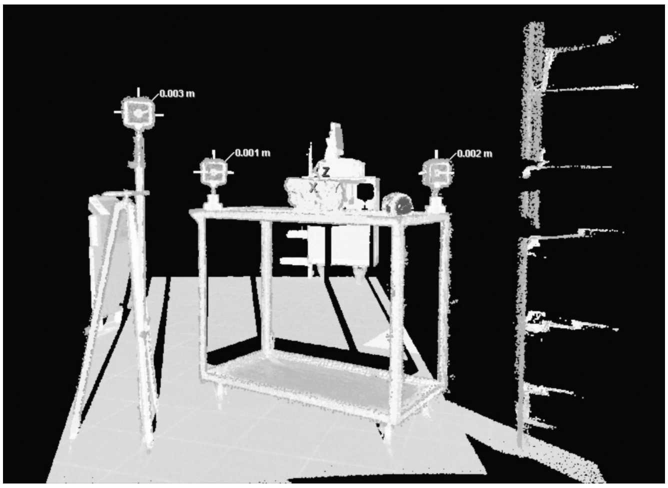

Fig. 3. Data gathering.

In the radiation of a point, precision was obtained at distances of ±4 mm and ±60 microradians per angle. The data capturing capability reached 1.000 points per second, achieving an internal precision in the range of 1,2 mm.

The points cloud was treated using the Leica software named Cyclone, which has calculation and modelling models in two and three dimensions. The intensity of luminosity was registered as the fourth coordinate.

Photographs for the textures were taken from a tripod, ensuring that the collimation axis of the camera was as perpendicular as possible to the photographed plane. Images were taken of all sides, with different focuses and illumination.

The triangulation of the digital model of the capital was carried out from the points cloud, imposing the following algorithms:

- All available points have been included on the triangular net.
- Triangles do not overlap.
- The triangle sides are of the same length.
- The triangles are as equilateral as possible.

With the model of the capital, the net was softened so that the surfaces obtained a uniform aspect. The textures were retouched with the image-processing programme Adobe Photoshop 5, and the model was mapped using the options of cylindrical or flat, sides, and adjustment with traction. To obtain the mapping coordinates, each element was assigned a material, taking into account its size and the location of the photograph.

Once a realistic representation of the capital was achieved (Fig 5), an animation of the model was carried out, locating the position of the cameras and determining their characteristics of focus, environment range, clipping frames, and trajectories. In order to obtain the desired result, the illumination of the environment was taken into account by positioning lights of different intensity and colour.

The animation of the camera was undertaken by describing the three-dimensional trajectory of translation. Once the camera was animated, a concatenation of frames was carried out, in order to simulate the apparent movement, projecting consecutive images at high speed. Finally, sound was incorporated.

In addition, the MDT was sent to computer science research groups for processing into 3D computer games and puzzles.

3.3 Other Sources of Information

At present, we can identify high-resolution spectographs and radar technology as future commitments for digital cartography. Remote Sensing systems detect and measure electromagnetic perturbations that the objects under study induce on their environment, for these, a series of instruments (sensors) placed on aerial or spatial stations, or on the ground are used.

Traditionally, cartography has been considered as an intermediate product in remote sensing, used for the best of cases, and not as an aim in itself. This response is logical in the first phase of appearance and settling. However, the potential of the new generation of sensors, both from the spectral and the spatial viewpoint, encourage us to affirm that they are an extraordinary alternative to the elaboration of basic and thematic cartography, with the enormous range of derived products they can give rise to in the documentation, register and distribution of archaeological objects

Conversely, radar technology is sufficiently established, although still under development. However, technology allows the processing of a direct georeferentiation of images, or, in other words, the cartographic automatic projection of the images.

4. Archaeological Distribution

4.1 Multimedia Applications

In order to introduce and represent the archaeological information pertaining to the capital, multimedia techniques were applied, to offer a clear and simple access and direct the information towards all types of users, considering the educational, domestic, leisure, technical and professional markets.

The differences in the multimedia editing process with regard to the paper format are the different integrated means, the component of development and programming, the necessity to create a non-linear script, and to establish the adequate levels of user interface and interactivity. With this aim, we used Macromedia Freehand 8.0, Photoshop 5.0, Microsoft Word and Director 8.0 software. The final result was a document able to self-run and show its entire graphic, textual and audiovisual content.

Once the archaeological information of the capital was gathered and processed, the multimedia application was developed, integrating the documentation with the programme Director 8. This tool allowed us to work in an intuitive and efficient way, using the metaphor of assimilating the creation of the application to a cinematographic film, where the author of the application is also the director responsible for placing the actors in different sequences, controlling their appearance on screen and their movements.

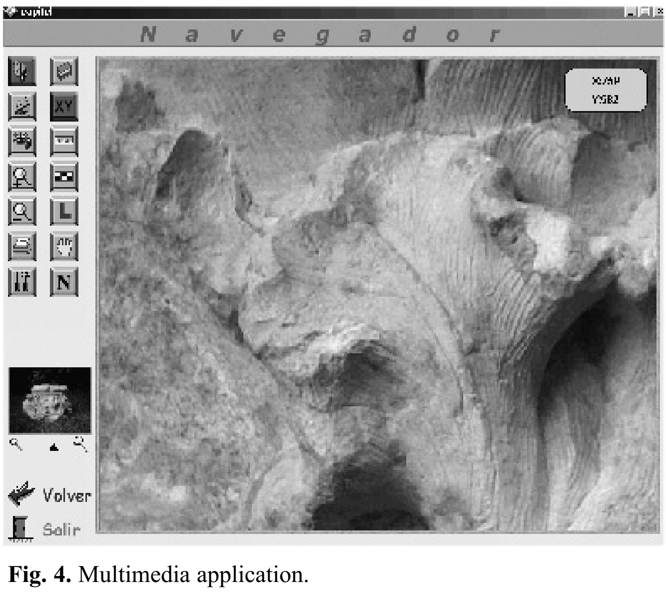

Fig. 4. Multimedia application.

The LINGO module was used, which programmes by relating the user to the interactive elements link, with some commands that constantly evaluate the state of the application and the position within the level of information (Fig. 4).

The information used has been cartography, texts, images, sounds, and videos. The textual and graphic information was provided by the administration and the excavation team and complemented with bibliographic material. The text helps to explain that which could not be interpreted with only the maps and images, by relating part of the story, interpreting the meaning of a key or navigating through different screens. In order to clearly communicate the results, the content of the texts was simple, concise and direct. The style, size and colour have been chosen for each particular case. Graphs have been used for the spatial representation of the capital and to show its descriptive features. On the other hand, images offer the possibility of animation. Greater perception and visual retention of the information depend on these. The existing interaction in the video sequences offers a substantial descriptive potential. And, finally, sound has been used to set and highlight the archaeological piece. The sound register has been produced from compact discs and computer sound files. It was decided that the nucleus of the application should be constituted by a plane that clearly displayed the capital, offering a global conception of its aspect. This document was obtained through the rectification of images using photogrammetric procedures. The support points were obtained using two T2 theodolites of an angular precision of a centesimal second.

Due to the screen visualisation problem, as the ortorectified document was larger than the screen, it was given movement. This way, the part of the capital requiring viewing, could be seen almost immediately. The movement of the capital can be carried out through small movements, by using the upwards or downwards, right or left arrows, or through greater movements on a small sketch in which a square appears showing the visualized area, which can be moved to the desired spot. It also has a built-in zoom function, which does not involve a change in scale, but, simply, a better visualization of the archaeological object. An important feature of the application is that it enables metric analyses in real time.

The application has a tree structure that permits navigation in the programme by passing through different menus and submenus in order to reach a detailed level of information. In order to facilitate navigation, a help screen, which can be accessed from any of the screens, as well as a locator, which indicates the level of information, were created. This permits the transference onto screen of similar levels of information, without the need to return to the menu or submenu.

4.2 Other Sorts of Dissemination

Following the computational process described, we decided to face the fact that in this work only one viewpoint had been considered: "the archaeological object as a technological object", and decided to change it, stating a new principle: *"the archaeological object as an art object".*

Obviously, the metric documentation of the capital is very important. However, in its register procedure we constantly questioned up to what extent? and the option of doing this another way.
In this sense, the first step was to recuperate the object itself, and, for this, we required the cooperation of the professional photographer D. Jaime López, to develop traditional postcards. These postcards can explain what it is to the observer without forcing him or her to carry out collateral approaches.
By manipulating the traditional photograph, sequences such as the one observed in Fig. 5 are obtained.
Likewise, regressing slightly in time, we moved the capital to the art atelier Látelier (www.latelier.es). Where, it was used as a model in the painting and drawing courses taught there. New forms of expression appeared from this experience, models that significantly surpass any virtual representation or digital model, such as those produced by D. Santiago Moliner and D. Guillermo Moliner.

Fig. 5. Photograph in sepia colours.

Our work continued, and we presented the challenge of incorporating the videographic to D. Martín Carril, making the virtual representation obtained using the 3D scanning system available to him. Among his works, the following must be pointed out:

- The Reflection in Water
- The Dance of the Meteorite
- The Loneliness of the Stone
- The Four Moons
- The Vegetal Stone

All of them are a way of interpreting archaeological reality, equipping them with scenery and sound. Fig. 6 shows a scene from the animation The Reflection in Water. With this image we can complete the circle of the metrical and distribution analysis which we have been researching, reminding you of the moment in which the capital was found on the riverbed near Recópolis, and reconstructing the instant in which the capital emerged from the water to become the protagonist for all our adventures.

Fig. 6. “The Reflection in Water”.

5. Summary

Throughout our paper, we have shown different techniques that can be used to document and record archaeological findings. We can give the object coordinates on a geodesic reference system, elaborate the cartography of its environment, incorporating its place in history, represent its physical representation right down to the millimetre and describe it geomorphologically, and obtain its digital model and virtual representation. We cannot leave aside the question of reality and up to what point we have separated from this as we were carrying out all these processes.

The capital is our protagonist. However, is the protagonist the one from the past or will we be able to make the future capital become the protagonist? What has the archaeologist’s intervention amounted to? What is the desired knowledge regarding the piece? What are the limits between technique and art? Are they complementary? Does archaeology die during the process? What must be distributed and to whom?
Archaeology without the archaeologist can be submitted to all sorts of technologies, as has been seen throughout this paper. However, the person who must connect the past and the future, through archaeological findings, has to be the archaeologist. Technology is an accessory the archaeologist should use, directing it towards the real objectives of research.

We leave the question open: *Has an artefact been displayed thanks to technology and without reference to the archaeologist?*.
And we leave you with this poem:
“New technologies enable us to disclose the object as something unique, with a life of its own. It is as if the very texture of the stone takes on the appearance of a weather beaten face, which reflects a experience.

The capital has its own history, which begins the moment that the sculptor carves the shape from the stone, and extends from then into eternity.

In contemplating it we are wont to reflect on time, that most precious of gifts, since as humans we are but the stones from which the great arch of history is contructed, and our technologies serve as instruments in the search for beauty".

Acknowledgements

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