MULTI-RESOLUTION DIGITAL 3D IMAGING AND MODELLING OF THE GROTTA DEI CERVI

J.-A. Beraldin[1], F. Blais[1], L. Cournoyer[1], M. Picard[1], D. Gamache[1]
V. Valzano[2], A. Bandiera[2]
M. Gorgoglione[3]
[1]IIT, National Research Council Canada, Ottawa, Ont, Canada, K1A OR6
[2]SIBA Coordination, University of Lecce, LE, Italy, 73100
[3]Superintendence of Archaeology of Apulia, Taranto, Italy

ABSTRACT

The Grotta dei Cervi is a complex and fragile Neolithic cave where human presence left a large number of unique pictographs. Detailed documentation necessitates recording it at different levels of detail (spatial resolution). We used a prototype multi-resolution 3D laser imaging scanner that allowed acquiring the shape information of the four main chambers with a spatial resolution that improves with shorter standoffs ranging from 10 m down to 0.5 m. At a standoff of 0.75 m, the depth uncertainty is 0.08 mm and the lateral resolution is 0.2 mm on the actual rock surface. The 10-day scanning project generated over 100 GB of 2D and 3D images that will require the development of new tools for modelling and managing the archive.

Figure 1: Grotta dei Cervi, Neolithic cave, Italy (40°04'47"N, 18°29'02"E).

1. Introduction

High-resolution 3D models of museum objects and heritage sites contain a wealth of information that can be examined and analyzed for a variety of conservation, research, and display applications [GBT*02]. For example, in the case of a site that must be closed or subjected to limited access for conservation reasons, an immersive 3D virtual reality theatre can be used to enable visitors to "virtually" visit the site. Researchers can zoom in on a 3D model to examine, measure, and compare fine surface details for signs of deterioration or to examine tool mark features. In contrast to photographs, the actual geometric 3D position of each point on the surface of the model is available. Computer-based visual enhancement and analysis techniques can be applied to accomplish a precise "virtual restoration" that cannot readily be accomplished using traditional conservation techniques. Enhancement techniques can improve the legibility of faded images or inscriptions as well as remove graffiti that has defaced the images. Finally, 3D models recorded before and after an actual conservation treatment, can serve as vital archival record for ongoing site monitoring and maintenance.

The accurate recording of rock art sites, ancient crypts and grotto sites is a challenging task. These sites have either formed naturally or been carved from the surrounding rock and typically the walls, floors, and ceilings have an irregular surface shape and the paintings (pictographs) or carvings (petroglyphs) follow the contours of the rock surface over large areas. These features, particularly the shape of the rock surface and speleothems (wall concretions, stalactites), are difficult to record with a high level of detail, measure, compare and display using conventional recording techniques such as survey methods, rectified photography, distance meters, etc.

The "Grotta dei Cervi" project started in February 2004, and it aims at recording the shape and appearance of that cave and to push 3D technology to higher levels. The site is composed of three main corridors decorated with Neolithic pictographs made of red okra and bat guano [Gra02]. The Grotto discovered in 1970 by local speleologists is located near Porto Badisco, Italy. The main entrance is situated at 26 m above sea level and the largest depth is about 26 m. The temperature is fairly constant at 18°C and the RH hovers between 98% and 100% [LGS*00]. The main motivation for this project comes from the fact that the cave is closed to the public and only a limited number of experts are allowed in every year. This measure is necessary in order to preserve the delicate environmental balance inside the site. Consequently, a detailed 3D model draped with colour information would allow for increased information through detailed studies and virtual visits without traumatic consequences to it.

2. Grotta dei Cervi: Practical considerations

The team had strict guidelines to abide to before entering the Grotto: emergency exits, equipment and first aid stations, drop cloths to be used for equipment and people, constant monitor of the temperature during the work, two speleologists present in the grotto at all time, no modifications allowed to the site to fit the equipment or people. The NRC team was composed of five individuals directly involved in the project and one programmer that stayed on-line in Canada. From the SIBA-University of Lecce, five individuals participated directly to the recording inside the Grotto and one programmer that stayed on-line outside. Two experienced speleologists and two archaeologists accompanied and took an active role during the recording. The project went according to plan with minimum modifications from the original schedule even when considering the complexity and difficulty of this very challenging environment: dust, humidity, and size, etc. To limit the quantity of equipment inside the Grotto and to adapt quickly to the unpredictability of the irregularly shaded walls, we used an extensively modified prototype high resolution 3D laser imaging scanner developed at NRC. It acted like a three-in-one laser scanner. For texture acquisition, four short duration 500 watts•sec flashes were used. A low noise power generator, one UPS, two parallel electrical power lines of 300 m long: one for the 3D laser scanner, and the second for the flashes. An Ethernet link insured constant cave to surface communication, backup and data transfer between the computers.

3. NRC's 3D technology & Preliminary results

The scanner used for this project is known as "Big Scan" laser scanner and is a research prototype system under development for high-resolution 3D digitization of large structures. A space qualified version of this scanner was built by a private company for inspection tasks for space shuttle missions. Big Scan uses a green laser to acquire high-resolution 3D images. Lateral resolution varies depending on the distance of measurement and the point density of the 3D images:

- 0.2 mm @ 0.75 m in very high-resolution,
- 0.4 mm @ 0.75 m for high-resolution,
- 0.75 to 1.0 mm @ 1.4 to 2.0 m for medium-resolution,
- 2 mm @ 2 m in low-resolution.

3D scanning

The 3D model is created by acquiring a mosaic of 3D images sections and by stitching these images by software. Overlapping areas between the 3D images is needed in order to properly align them together. An 8-Megapixel camera is mounted on the laser scanner in order to acquire high-quality texture images.

2D texture photography

Photographs of key critical sections of the grotto were acquired using a 14-Megapixel digital camera at two predefined pre-calibrated positions: 2.0 m for close-ups and infinity for global image modelling. These images will be used to provide very-high resolution (4500 × 3000 pixels) colour texture mapping on the 3D models for each section of the "Grotta".

Table 1: Project "Grotta Dei Cervi" in numbers.

Number of rooms scanned	4
Smallest spatial resolution	0.2 mm for both geometry and colour
Number of 3D images acquired	716 X-Y-Z
Number of 3D points acquired	630 million points
Number of 2D images acquired	3500 images
Total amount of data captured	100 gigabytes
Scanner weight	3 kg
Length of electrical cables Length of Ethernet cables	600 m 300 m
Narrowest passage	0.6 m x 0.6 m

A total of 35 GBytes for 716-3D images with photographs and 65 GBytes for 1786-high-resolution colour texture photographs were acquired. This very large amount of high-resolution 2D and 3D image data opens the door to providing a 3D model of the cave of unmatched resolution, never obtained before in any 3D model of a grotto site. This will be a major scientific milestone in modelling large and complex 3D environments. Our major challenge is associated with the size and resolution of the 3D images which causes computer crashes and excessive processing time. We are pushing the image resolution by almost an order of magnitude compared to previous work which implies that even the limits imposed by the computer operating system, for example 1.7 GBytes for Windows, is becoming a major problem.

4. Conclusion

Three-dimensional models of ancient rock art sites, ancient crypts and grotto provide an important new level of documentation, which can be used for a variety of conservation, research and display applications. Perhaps the most important is that 3D VR theatre displays of accurate virtualized models of those sites can be used to enable very realistic virtual visits to the sites in lieu of actual site visits, which endanger the site itself.

A second very important application is the use of the data to reliably monitor the condition and stability of the site.

The problem we addressed and the approach we proposed in this paper are aimed at the effective use of 3D modelling to enhance the understanding of a heritage site that needs to be preserved and shown to more people in order to raise awareness and understanding of rock art sites that are fragile, inaccessible and usually located in remote areas. The work will continue and we expect to do more research to create tools that will handle the models that will be created from the 100 GB of 2D and 3D data generated in the course of the 10-day visit to the grotto. Those models will be used for public outreach purposes and experts will have access to the data through collaborative projects. More research work is required to speed up the process of acquisition and modelling. But one needs to understand that the current level of recording efforts and cost are worth spending compared to risking the forever loss of important historical sites to vandalism, natural disasters or wars.

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