Assembling the Sculptures of the Parthenon

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Although the Parthenon has stood on the Athenian Acropolis for nearly 2,500 years, its sculptural decorations have been scattered to museums around the world. Many of its sculptures have been damaged or lost. Fortunately, most of the decoration survives through drawings, descriptions, and casts. A component of our Parthenon Project has been to assemble digital models of the sculptures and virtually reunite them with the Parthenon. This sketch details our effort to digitally record the Parthenon sculpture collection in the Basel Skulpturhalle museum, which exhibits plaster casts of almost all of the existing pediments, metopes, and frieze. Our techniques have been designed to work as quickly as possible and at low cost.

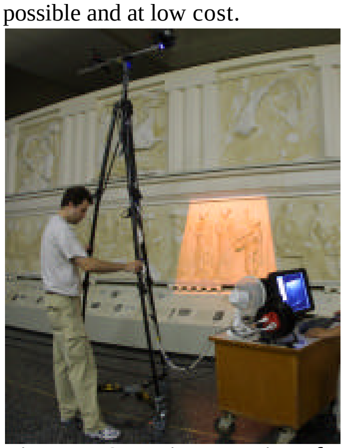

Figure 1: Scanning a section of the east frieze.

Since the Parthenon sculptures are numerous, we designed a scanning system optimized for speed at 1mm accuracy rather than for maximal accuracy as in [Levoy et al. 2000]. To address this we built a custom structured light scanning system using a Pulnix TM-1040 black and white CCD camera, a Proxima Ultralight x350 DLP projector, a simple mounting system, a large checkerboard calibration object, and a portable computer. The system allowed us to capture 3D scans at 1024x1024 resolution at less than 30 seconds per scan. Using new algorithms for depth estimation from structured lighting [Tchou 2002], we achieved a depth resolution of better than 0.2mm at each pixel. Reflectance information from the casts was recorded in color by projecting red, green, and blue light onto the casts with the video projector. Because of the efficiency of the system, we were able to scan over 440 linear feet of frieze, 52 metopes, and both pediments in just five days with a team of four people, totaling nearly 2,200 individual scans.

Our calibration process involved scanning a flat checkerboard grid pattern in several orientations, allowing us to solve for the distortion characteristics and the relative orientations of the camera and projector. We developed methods for extracting these calibrations using HDRShop and Matlab, and then streamlined the process into a single Windows application. Given such calibration parameters and a scan of a sculpture, the 3D structure of the visible surface is triangulated.

We found it was faster to remove undesirable geometry in the 2D camera image space before the scans were converted to 3D meshes. For this we developed a program that allows the user to view the scanned surface normals and mask out specific regions. To fill geometry holes caused by occlusions in the scan images, each sculpture was scanned from multiple angles. Because scans were captured from different vantage points, they needed to be aligned to each other. In many cases, such as the frieze, the sculpture pieces were arranged lengthwise in the museum, allowing us to take the scans at regularly spaced intervals. By deriving the relationships between the first few meshes, an initial estimate of relative alignment could be propagated to the rest of the scans in that section of frieze, and then refined using the Iterative Closest Point (ICP) algorithm. We used MeshAlign 2.0 written by the Visual Computing Group at the Istituto di Scienza e Tecnolgia dell'Informazione-C.N.R to perform both the initial point-based alignment and ICP. We also used their surface reconstruction program [Cignoni et al. 2003] to merge our aligned meshes.

Figure 2: Assembled scans of south metope 29

Our scanned models have allowed us to combine the sculptures with models of the Parthenon from several eras and to create virtual renderings using both global illumination rendering and subsurface scattering techniques. The sculpture database forms the basis of the next phase of the project: to produce restored models appropriate for the original Parthenon based on archeological research. This project provides a nuts and bolts example of how advanced technologies can be applied in archaeological contexts quickly and at low cost.

Figure 3: The west pediment scans have been placed in "situ" on a model of the Parthenon c. 1800.

References

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