Scanning Michelangelo's Florentine Pietà: Making the Results Usable

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Abstract

We describe a project to create a three dimensional digital model of Michelangelo's Florentine Pietà. In particular, we examine how to edit and interactively view the model that consists of millions of triangles and hundreds of color and normal maps.

1. Introduction

We have been engaged in a project to create a three dimensional digital model of Michelangelo's Florentine Pietà [1, 2]. The model is being used by art historian Dr. Jack Wasserman in a comprehensive study of this sculpture that includes a consideration of historical records and religious significance as well as scientific data. The 2.25 m statue is shown in a photograph in Fig. 1. The detail of the digital recon struction is shown in the synthetic image in Fig. 2.

The technical approach to acquire data and construct the model has been described in previous papers. Briefly, a combined multi-view and photometric system was used to capture hundreds of small meshes on the surface, each with a detailed normal and color map aligned to the mesh [5, 4]. The meshe s were aligned, and merged into a single triangle mesh using the ball pivoting algorithm [3]. The result is a triangle mesh model consisting of millions of triangles and hundreds of normal and texture maps. Since the model is still being refined, we do not yet know the final size of the complete model.

Figure 1: *A photograph of Michelangelo's Florentine Pietà*

Figure 2: *A synthetic image showing a detail of the scanned model*

Regardless of how efficiently the model is ultimately represented, the full mesh and maps will be too large to conveniently interact with on a high end personal computer. As difficult as it is to acquire the three dimensional model in the first place, we have to address the additional difficult

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problem of making the model accessible to art historians for study.

There are a number of issues that are of interest to an art historian to pursue with the digital model. These include:

- Viewing the sculpture with alteration in geometry. In the case of the Florentine Pietà there are at least two useful alterations to make:
  - Removing the portions of the statue that were removed by Michelangelo himself and later reattached by another artist. Understanding why Michelangelo apparently damaged his own work is an open question.
  - Separating the four figures to study their proportions individually. The figures are not shaped like normal humans, but are designed for specific effect in the sculpture. Viewing the figures individually gives the art historian a new perspective on how Michelangelo worked.
- Viewing the sculpture as a whole from precisely defined viewpoints. The sculpture is not currently displayed as contemporary records describe the artist's original intent. Preliminary views indicate that when viewed from below, as it would have been if installed above the artist's tomb where he intended the work to be displayed, the leftmost figure is much better integrated into the work than when viewed at the height it is in the museum today.
- Viewing the sculpture in detail to catalog the artist's toolmarks. Because the piece was broken by Michelangelo and never finished, the raw tool marks have not been polished away. Viewing the marks gives insight into the artist's technique.

Initially the technical team has worked with the art historian to use the digital model to obtain some preliminary insights. However, the digital model will be the most useful when the art historian doesn't have to work through another human being to obtain configurations or views. Furthermore, a long term goal is to make the model accessible to future art historians to use to either confirm or refute conclusions Dr. Wasserman reaches in his study.

2. Editing Geometry with Images

Altering the model to remove the broken pieces, and to separate the figures, is a difficult task. It is particularly tedious to edit a mesh of millions of triangles, where just the response time on a simple "pick" can take seconds. Many interactive tasks are made easier using a simplified geometry. For detailed editing of a model, however, a simplified form is not satisfactory.

The editing task is made even more difficult, in that we wish to edit many different versions of the model. In the course of our project, we are developing more accurate methods for reconstruction, and more efficient representations. Simultaneously, we wish to provide Dr. Wasserman with many intermediate results so he can begin his studies. We need to somehow indicate the edits in a form that can be repeated on many different meshes generated from the input data.

Figure 3: *(Top) Original texture map from statue (Bottom) Texture map color coded for three dimensional editing.*

Ultimately, we decided to define cuts on the model by editing the texture maps that are applied to the triangle mesh. An example of a texture map edited to separate two of the figures shown in Fig. 3. By checking the color associated with each point in the mesh in its texture map, a point can be included or excluded from the model based on either which of the four figures it belongs to, or on whether it is a piece of the statue that Michelangelo broke off.

In the future, this same mechanism could easily be used to identify other portions of the sculpture to be isolated and studied. For the non-technical user of the data, this type of simple editing of complicated three dimensional geometry can be reduced to using any common two dimensional paint program.

3. A Hybrid Viewer

The other tasks involved in study require viewing the sculpture over a wide range of length scales. To deal with the range of scales, we have designed a hybrid model-based/image-based viewer. The viewer is based on the following ideas about perceiving shape:

- Large scale features of shape and proportion are revealed by changing view. Silhouettes and occlusions change as view is changed.

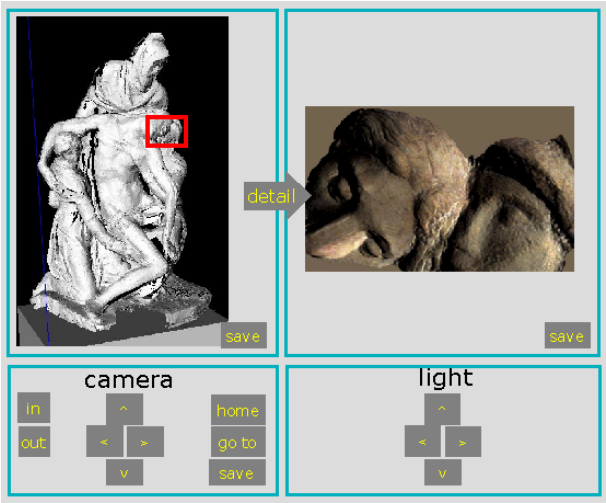

Figure 4: *A hybrid model-based/image-based viewer.*

- Small scale features of surface roughness are revealed by changing lighting. There may be essentially no changes in the silhouette or occlusions when looking at a small portion of a rough surface from different points of view. However, the changing patterns of shadows as the lighting changes reveals the size and sharpness of small geometric features.

The design is shown in Fig. 4. On the left a simplified model of the statue is shown. The view can be changed with a simple set of buttons. This allows the historian to examine proportions and composition of the statue when viewed at precisely defined and repeatable heights and angles. Because the entire statue (2.25 m) is in view, there is no need for the full resolution model.

On the right side is a detailed image of a small portion of the statue. The detailed image consists of two layers – one with the normal vector at each pixel, and one with the color at each pixel. The light source direction can be varied with a simple set of buttons similar to the view control buttons. Variations in surface roughness can be examined in this magnified view.

The two sides of the viewer are linked by the user's ability to specify the detailed view on the simplified model on the left. The area selected by the user in the red rectangle, along with current camera parameters, are sent to an offscreen renderer to construct the normal-plus-color image to be used on the right from the full resolution model. To use the complete model, the viewer needs to be networked from the user's personal computer to a large scale server. For stand alone applications, the resolution of the full model to be used by the offscreen renderer can be reduced to run in a reasonable time on the user's computer.

Using the hybrid viewer, the user can examine detail, without losing context. The hybrid viewer requires fewer computer resources, and much less user expertise than a viewer that attempts to present continuous level-of-detail updates as the viewer zooms in on a region of interest.

The hybrid viewer is a work in progress. We expect that the design and function of the viewer will continue to evolve as we continue to work with Dr. Wasserman.

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