Enhancing surface features with the Radiance Scaling Meshlab Plugin

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Abstract

We present the new Radiance Scaling plugin for Meshlab. This rendering technique allows depicting shape through shading via the modification of light intensities around specific features. The major idea is to correlate the shading with surface feature variations in order to enhance shape details like concavities and convexities. The Radiance Scaling rendering technique works in real-time on modern graphics hardware. As a consequence, surface features can be inspected interactively. Recently, the Radiance Scaling technique has received major interest in the French Archaeology research community, in particular for enhancing details in carved stones and thus improving their legibility.

Keywords

Meshlab, 3D shape depiction, 3D surface analysis, feature highlighting

1. Introduction

The 3D acquisition of cultural heritage artifacts is becoming more and more common. Most often, the surface of the artifacts is either directly acquired by 3D laser scanning, or obtained by 3D photogrammetric reconstruction, followed by a 3D point to mesh conversion. One of the first motivations for 3D acquisition was to digitally preserve cultural heritage. More recently, it has been shown that for broken artifacts, the separate 3D acquisition of each fragment may offer the possibility to virtually reconstitute the past by computer aided reassembly.

During the virtual inspection of the acquired artifacts, the maybe most important element is the 3D visualization. Nowadays, the advances of computer hardware and especially the graphics cards make it possible to render photo-realistically the meshes of 3D models consisting of millions of polygons.

We are convinced that the inspection of 3D models is further improved when they are visualized *non*-photo-realistically with modern 3D expressive visualization techniques. With the exaggeration of several surface features according to the geometry of the 3D model, these techniques may better depict shape characteristics. Emphasizing meaningful portions of the surface and hiding the meaningless ones creates a far more legible pictorial representation, and removes possible ambiguities.

In this work, we present a specific expressive visualization technique called *Radiance Scaling* that we integrated as a plugin for the 3D model processing software *Meshlab*. This rendering technique allows depicting shape through shading via the modification of light intensities around specific features like concavities and convexities. The Radiance Scaling rendering technique works in real-time on modern graphics hardware, making it feasible for an interactive inspection in Meshlab.

We believe that the choice to integrate Radiance Scaling as a plugin in Meshlab is the perfect means for a widespread use, because we observed a growing interest in Meshlab, especially in the digital cultural heritage community.

This paper is organized as follows. In Section 2, After introducing Meshlab, we show some related work concerning expressive visualization with a special interest for cultural heritage applications. Then, we present the Radiance Scaling Plugin with all its options. In Section 4, we discuss a case study on a concrete example of using the Radiance Scaling plugin for deciphering inscriptions on an epitaph found near St. Emilion, France. Finally, we conclude with directions to future work in Section 5.

2. Related Work

2.1 Meshlab

Meshlab is an advanced 3D model processing software system for the processing, editing, cleaning, healing, inspecting, and visualization of 3D models.

It is particularly interesting for the research community for several reasons. From a general point of view, it is distributed freely, and as open source, and it is portable to a number of operating systems, and deals with a large variety of 3D mesh formats (e.g. PLY, STL, OFF, OBJ, 3DS, VRML 2.0, U3D, X3D and COLLADA), and even point clouds (e.g. imported from photogrammetric reconstruction such as *Photosynth*).

Meshlab is an extensible system, and from a computer scientist point of view, any developer can contribute to its improvement. The open architecture makes it possible to write I/O plugins for new 3D formats, to develop editing plugins for advanced mesh processing, and to propose new rendering styles, even for programmable graphics hardware. We made use of this latter for the integration of our new radiance scaling technique.

Meshlab has been developed since 2005, and the user and developer community is growing steadily, and especially in the digital cultural heritage context, where it has already proven to be beneficial.

2.2 Expressive visualization

The depiction of object shape has been a subject of increased interest in the Computer Graphics community since the work of Saito and Takahashi [1990]. Inspired by their pioneering approach, many rendering techniques have focused on finding an appropriate set of lines to depict object shape. In contrast to line-based approaches, other techniques depict object shape through shading. Maybe the most widely used of these is Ambient Occlusion [Pharr and Green 2004], which measures the occlusion of nearby geometry. Both types of techniques make drastic choices for the type of material, illumination and style used to depict an object: line-based approaches often ignore material and illumination and depict mainly sharp surface features, whereas occlusion-based techniques convey specifically depend on sky-like lighting environment.

Among the recent techniques, the work of Vergne (Vergne 2009) is receiving a raising interest thanks to its simple integration into a large range of shading techniques. For Radiance Scaling (Vergne 2010), the key observation is that reflected lighting variations are correlated to surface feature variations. For example, consider a highlight reflected from a glossy object: by increasing reflected light intensity in convex regions and decreasing it in concave ones, the highlight looks as if it were attracted towards convexities and repelled from concavities. Such an adjustment improves the distinction between concave and convex surface features, and does not only take surface features into account, but also material characteristics.

3. The Meshlab Plugin Radiance Scaling

For Meshlab, we implemented a simplified version of Radiance Scaling, taking into account the feedback of cultural heritage professionals during several projects. This implementation is a simple plugin, accessible in the Meshlab menu "*Render > Shaders*".

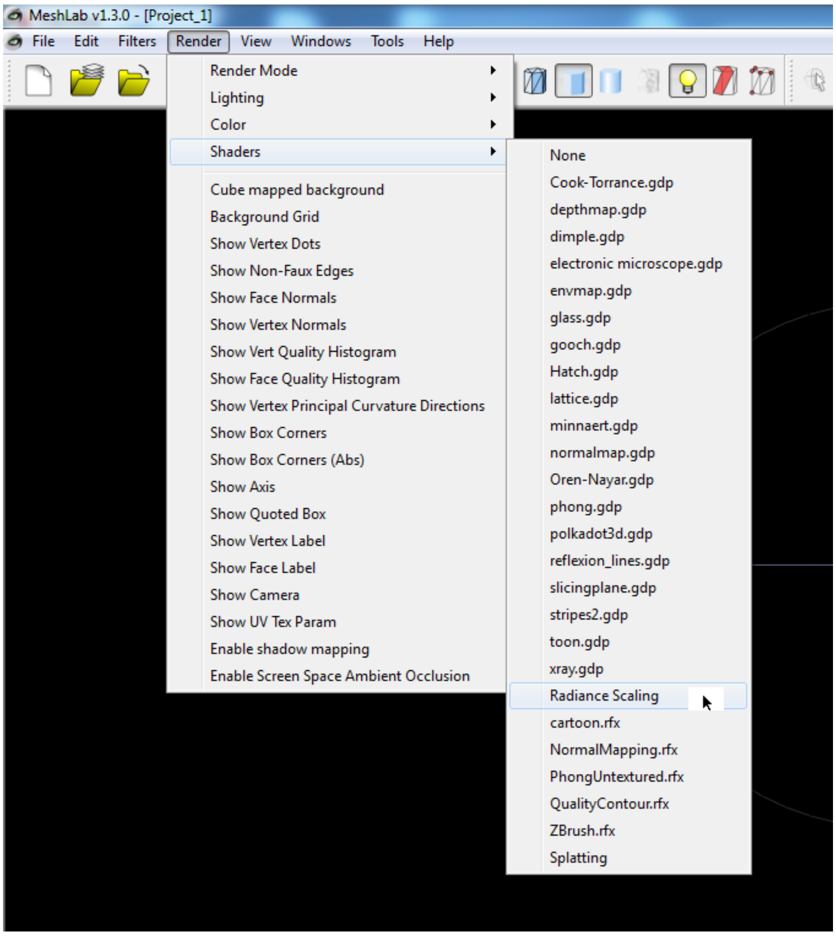

Figure 1: Selection of the Radiance Scaling Plugin

Once selected, our Meshlab Radiance Scaling Plugin provides four general options:

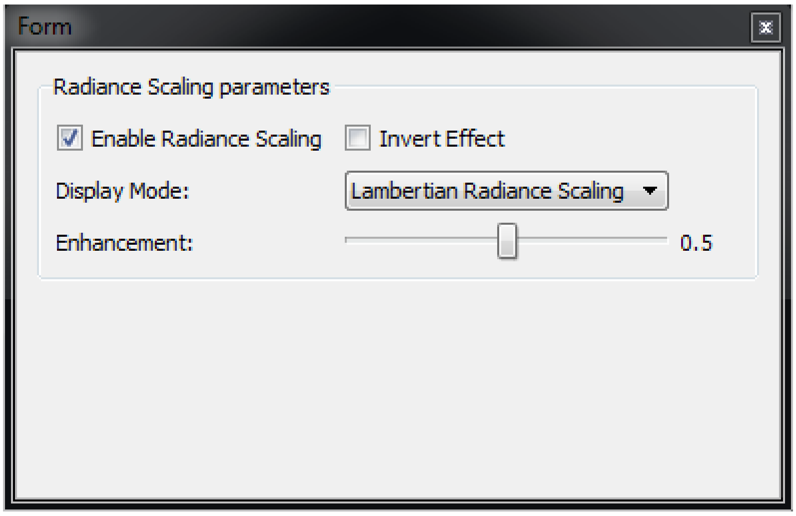

Figure 2: Available options of the Radiance Scaling Plugin

1. *"Enable Radiance Scaling":* activate or deactivate the shape enhancement.
2. *"Invert Effect"*: the rules of concavities and convexities are inverted. This has proven to be useful in certain cases for providing more legible results. In fact, it mimics the work of archaeologists when making squeezes of ancient imprints.
3. *"Display mode"*: choose the different shading styles. The different styles are described below.
4. *"Enhancement"*: the enhancement factor that can be adjuster between 0 and 1, with 0.5 its default value. A 0-value corresponds to no enhancement, and thus has the similar effect as turning off the shape enhancement.

Among all the shading possibilities with Radiance Scaling, we decided to implement four of them since they are quite intuitive to use:

1. *"Lambertian Radiance Scaling"*: the object is rendered with diffuse shading.
2. *"Lit Sphere Radiance Scaling"*: A lit sphere (Sloan 2001) encodes the lighting environment and reflective properties into an image of a sphere. For further improving the legibility, a different lit sphere can be used for convex and for concave regions.
3. *"Colored Descriptor"*: Convexities and Concavities are displayed with two distinct colors (blue an red)
4. *"Gray Descriptor"*: we simply show the enhancement factor for each position of the object.

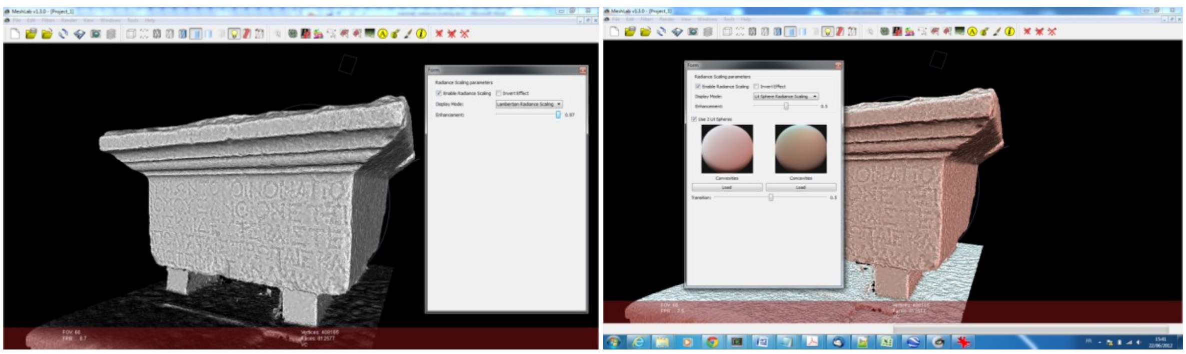

Figure 3: A working session with the Radiance Scaling Plugin in Meshlab.

4. **Case Study : The Epitaph of St. Emilion**

During an archeological study of the medieval Saint Emilion, some researchers were facing problems to decipher the inscriptions of the Costaulus epitaph, situated in one of the underground monuments in Saint Emilion. For the preparation of the virtual inspection of the engraved stone, a 3D acquisition of the artifact was done with a Faro ScanArm (Figure 4), by Pascal Mora and Robert Vergnieux PFT3D, CNRS UPS 3551.

Figure 4: (a) The Saint Emilion Epitaph. (b) The 3D scanning of the epitaph.

The resulting 3D model consists of over 7 million polygons (Figure 5).

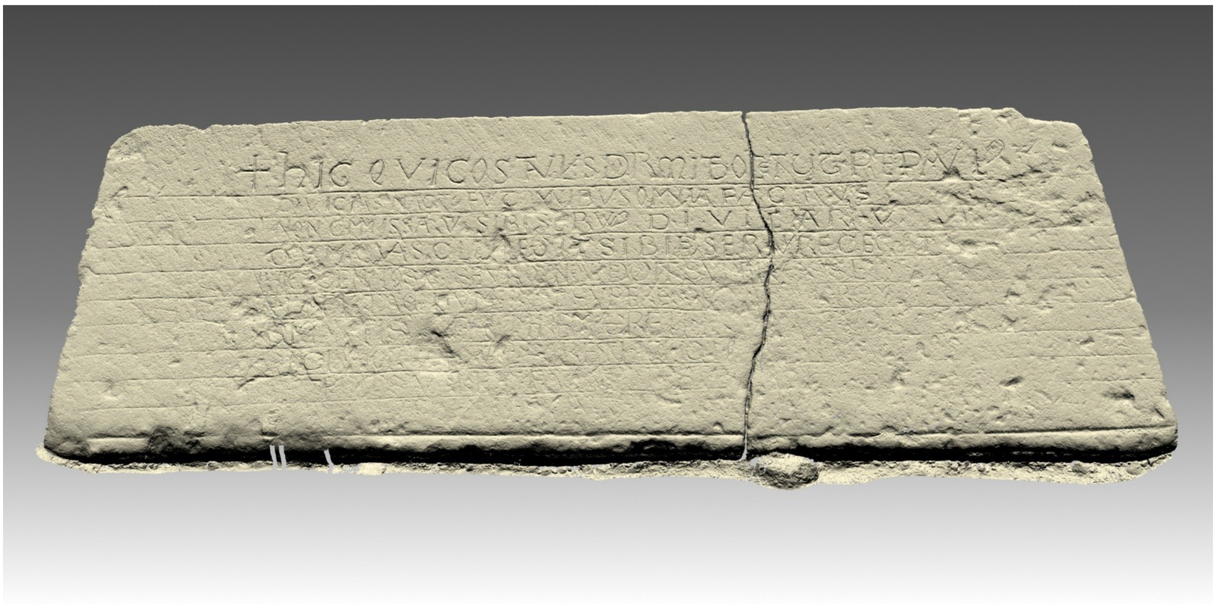

Figure 5: The reconstructed 3D model of the epitaph.

The 14-lines long inscription is situated on a calcaire bloc with a length of 2.1m and a height of 0.7m. The Meshlab Radiance Scaling Plugin helped to decipher the most erased parts of the inscription, and to reject the hypothesis about the presence of an inscription of the name "Emilion".

Figure 6: Shape depiction with the Radiance Scaling Plugin.

Figure 7: Radiance Scaling of an engraving with lit sphere.

5. Conclusions & Future Work

In this paper, we presented the Radiance Scaling Plugin for Meshlab. We have shown that this expressive visualization technique enhances the legibility of acquired 3D models through selective shading, and that the techniques can be made easily accessible via the integration into Meshlab.

In current and future work, we strive to integrate other useful expressive visualization techniques in Meshlab. For instance, we are convinced that the surface relief analysis technique (Ammann 2012) is particularly useful for the digital squeeze, since details at multiple scales can be analyzed.

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