3-27-2015

3D Reconstruction of the Vascularity of a Stegosaurus Dorsal Plate and an Alligator Scute

Dan Deifenbaugh
Indiana University - Purdue University Fort Wayne

Benjamin Aeschliman
Indiana University - Purdue University Fort Wayne, aescbd01@ipfw.edu

Paul Barrett
Natural History Museum, Cromwell Road, London

Charlotte Brassey
Natural History Museum, Cromwell Road, London

Shoji Hayashi
Osaka Museum of Natural History Nagai Park, Japan

See next page for additional authors

Follow this and additional works at: http://opus.ipfw.edu/stu_symp2015
Part of the Chemistry Commons, and the Earth Sciences Commons

Recommended Citation
Deifenbaugh, Dan; Aeschliman, Benjamin; Barrett, Paul; Brassey, Charlotte; Hayashi, Shoji; and Kim, Beomjin, "3D Reconstruction of the Vascularity of a Stegosaurus Dorsal Plate and an Alligator Scute" (2015). 2015 IPFW Student Research and Creative Endeavor Symposium. Book 76.
http://opus.ipfw.edu/stu_symp2015/76

This is brought to you for free and open access by the IPFW Student Research and Creative Endeavor Symposium at Opus: Research & Creativity at IPFW. It has been accepted for inclusion in 2015 IPFW Student Research and Creative Endeavor Symposium by an authorized administrator of Opus: Research & Creativity at IPFW. For more information, please contact admin@lib.ipfw.edu.
Authors
Dan Deifenbaugh, Benjamin Aeschliman, Paul Barrett, Charlotte Brassey, Shoji Hayashi, and Beomjin Kim

This is available at Opus: Research & Creativity at IPFW: http://opus.ipfw.edu/stu_symp2015/76
Three Dimensional Reconstruction of the Vascularity of a Stegosaurus Dorsal Plate and an Alligator Scute

Dan Debenbaugh: Department of Geosciences, Indiana-Purdue University Fort Wayne
Ben Rischmann: Department of Visualization and Information Analytics, and Visualization Center, Indiana-Purdue University Fort Wayne
Paul Barnett: Head of Division, Earth Sciences Department, Vertebrates and Palaeontology Palaeobiology, Natural History Museum, Cromwell Road, London
Charlotte Brassey: Department of Earth Sciences Natural History Museum, Cromwell Road, London
James Farlow: Professor of Geology and Palaeontology Department of Geosciences Indiana-Purdue University Fort Wayne
Shop Hayashi: Osaka Museum of Natural History Naga Park, 1-23, Higashi-Sumiyoshi-ku, Osaka, 554-0834, Japan
Beomjin Kim: Computer Science Department and Information Analytics and Visualization Center at Indiana University-Purdue University Fort Wayne

ABSTRACT

Three-dimensional models of the dorsal plates of the thyrhophorous dinosaur Stegosaurus and the osteoderms of an extant alligator (Alligator mississippiensis) were constructed utilizing 3D vision technology to study the potential vascular structures for the dermal ossifications of both species. 3D (stereoscopic) vision devices, which present two different images of a 3D object capture from the same projection plane, allow users to perceive depth from a rendered scene that is natural and intuitive to comprehend when compared with a 2D object rendered on a traditional 2D screen.

A system was developed that displays surface models of the each structure’s exterior and the possible soft tissue areas of the interior. Cross section images were created from volumetric CT scan images, which had potential soft tissue areas highlighted using SPIERS software. The segmented volumetric data sets were transformed into triangular meshes using the Marching Cubes Algorithm. Phong shading was applied to the triangular meshes providing a surface model view from the CT scan images. The system superimposed two computer-generated surface models and a cross section image on two different viewpoints to render a stereoscopic view of the Stegosaurus dorsal plate and the Alligator scute.

The system provides several interactive data analysis tools which enable users to navigate the dermal plates of Stegosaurus in virtual space from various directions, locate the slicing plane for cross section images, and magnify areas of interest. The system allows users to interpret internal structures of fossils while referencing associated exterior surface models and cross-sectional images in stereoscopic vision. The models of the Stegosaurus dorsal plate and alligator scute allow users to visualize soft tissue/vascular areas that could have facilitated blood flow between the osteoderm and the animal’s interior, possibly allowing for thermal regulation.

Introduction

The thyrhophorous dinosaur Stegosaurus is well known for its dermal ossifications in the form of dorsal plates and tail spikes. Various researchers have observed large openings at the base of the dorsal plates of Stegosaurus, which penetrate into the interior of the plate, and have interpreted these openings as “pipes” which may have contained blood vessels to facilitate perfusion throughout a plate’s structure (Farlow et al., 1997; Buffardi et al., 1998; cf. Man et al., 2001). These results are consistent with earlier interpretations of Stegosaurus plates having a thermoregulatory function.

Two dimensional images on a flat surface have limitations for a researcher trying to visualize the internal configuration of a specimen with complicated interior features, so we developed 3D models from CT scans of both a Stegosaurus dorsal plate and a modern analogue, the osteodermal scute of an Alligator. These 3D images are more natural and intuitive to view than 2D images (Zelle and Figure 2004).

Materials and Methods

CT scans of both specimens were imported into the Serial Palaeontological Image Editing and Rendering System (SPIERS) software, which allows users to mark tomographic data sets, such as CT scan images, and convert them to 3D models (Setton and Russell Garnwood, 2014). Here the process involved analyzing CT scans of both specimens, looking for regions of reduced density which appear as darker areas of the image. These areas of reduced density which appear to follow distinct, observable channels from either the exterior surface to the interior surface that were highlighted with SPIERS software. Only the most prominent channels were highlighted.

Three-dimensional reconstructions of both specimens were created by using a system that displays two different models for each specimen and cross sectional images that are created based on user-specified arbitrary angles. One model shows the exterior, and the other is a surface model of the segmented “pipes.” Cross section images were reconstructed from volumetric CT scan images modified in SPIERS. These volumetric data sets consist of multiple 2D image spheres. There were 41 image slices for the dorsal plate of Stegosaurus and alligator scute with SPIERS software. These volumetric data sets consist of multiple 2D image slices. There were 41 image slices for the dorsal plate of Stegosaurus and alligator scute with SPIERS software. The segmented volumetric data sets were transformed into triangular meshes using the Marching Cubes Algorithm. Phong shading was applied to the triangular meshes providing a surface model view from the CT scan images (Phong 1975). Finally, the system superimposes two computer-generated surface models, and a cross section image on two different viewpoints, to render a stereoscopic view of the dermal ossifications of the animals.

Results

Both models depict regions of reduced density, starting at points at the base of the structures and extending to the interior. These open spaces or “pipes” spread out to the exterior surface at multiple locations in the Alligator scute. The Stegosaurus plate has channels extending up from the base of the plates to the exterior surface of the plate. This plate has grooves which branch out apically into the structure. The Stegosaurus plate also has smaller channels that extend out to the surface, which in at least one instance connect to surface grooves which may have been part of the external dermal vascular system. The ability to manipulate 3D models of internal vascularly provides better understanding of the structure of this system.

Future research

This approach will be extended to a larger sample of Stegosaurus plates and tail spikes, to see how consistent the internal patterns of vasculature are. We will examine plates and spikes from a completely particular specimen in the Natural History Museum (London) (Bressy et al., 2015) and specimens in other collections (Hayashi et al., 2012).

Three dimensional reconstruction of Stegosaurus plate YPM 57712 and Alligator scute. This approach will be extended to a larger sample of Stegosaurus plates and tail spikes, to see how consistent the internal patterns of vasculature are. We will examine plates and spikes from a completely particular specimen in the Natural History Museum (London) (Bressy et al., 2015) and specimens in other collections (Hayashi et al., 2012).

Neck plate and tail spikes of NHMUK R36790. CT scans from this and other Stegosaurus specimens will be compared with our models made from the Yale specimen in further work.

Transverse section through potential vascular region of Yale plate

Three dimensional reconstruction of Aligator scute with bone cut away to display greater detail of Internal pipes for vascular tissue highlighted red

Three dimensional reconstruction of Aligator scute with bone cut away to display greater detail of internal pipes for vascular tissue highlighted red

Mounting skeleton of Stegosaurus Field Museum of Natural History

This approach will be extended to a larger sample of Stegosaurus plates and tail spikes, to see how consistent the internal patterns of vasculature are. We will examine plates and spikes from a completely particular specimen in the Natural History Museum (London) (Bressy et al., 2015) and specimens in other collections (Hayashi et al., 2012).

Three dimensional reconstruction of Stegosaurus dorsal plate YPM 57712 and Aligator scute. This approach will be extended to a larger sample of Stegosaurus plates and tail spikes, to see how consistent the internal patterns of vasculature are. We will examine plates and spikes from a completely particular specimen in the Natural History Museum (London) (Bressy et al., 2015) and specimens in other collections (Hayashi et al., 2012).