Dawn of a New Era: Virtual Paleontology

By Eleri Edwards, June 2014
Intended for ABC Science

Cerro Ballena whale fossil (Source: http://cerroballena.si.edu/sites/default/themes/responsive_business/images/slide-image-1.jpg)

With the application of 3D modelling and printing technology, Paleontology has expanded to the digital realm. Virtual Paleontology, the production and study of digital fossil data, will enable museums to create digital databases of their fossil collections and apply analytical modelling techniques, such as pattern comparison and movement analysis.

In 2011, a massive prehistoric whale graveyard was found at Cerro Ballena, Chile during construction to expand the Pan-Pacific Highway. With only a month left of research time granted by the Chilean government, a combined group of Latin American paleontologists from Universidad de Chile, Museo Nacional de Historia Natural in Santiago, and Consejo de Monumentos Nacionales were joined by US paleontologist Dr Nick Pyenson and his team from the Smithsonian Institute. With little time to study the environment in which these fossils rested, Dr Pyenson brought with him Vincent Rossi and Adam Metallo from the Smithsonian Digitization team. The Smithsonian Magazine described the painstaking process they made: laser scanning over 40 complete and partial marine mammal skeletons. The most abundant were the rorqual whales, of different developmental stages. To give a sense of the size, one of the more complete rorqual skeletons, pictured above, was 8 metres (26 feet) long.

The Smithsonian Digitisation team are pioneers in their field. Their work in Chile is the first implementation of its kind. Not only were they able to digitally preserve the bones—now resting in Chilean museums—, but also the ecological surroundings in which they were found. With 3D models created from the scans the findings from the Cerro Ballena site, published in the Royal Society journal in January 2014, were able to derive that algae blooms were responsible for these numerous mass marine strandings. This conclusion came not only from the fossils, but also the ichnological (trace fossils such as footprints or burrows) and sedimentological (the accumulation of sediments) surroundings in which they had lain.

For each skeleton, the team used tightly calibrated laser scans to gather hundreds of xyz coordinates, with which to generate a 3D model. Today, while the Cerro Ballena site no longer physically exists, it is not lost to us. Dr Pyenson—the lead author of the paper—commented, “we can translate [the scans] into a number of different outputs, one of which is 3D printing.” Indeed, on June 3, 2014, the Smithsonian Institute unveiled the world’s largest 3D printed fossil whale, currently installed in the Smithsonian’s National Museum of Natural History.

Techniques

Virtual Paleontology has so far been slow to develop due to the prohibitive prices involved. The three major scanning techniques used to digitise fossils are xrays, laser scanning, and photogrammetry. The cost of the hardware, the proprietary software, and the cost of trained technicians, means that only the well-funded university departments and museums currently have the ability to advance into this new field.

The application of x-ray techniques to fossils was first recorded in the 1970’s using computed tomography (CT). Because CT scanning is capable of differentiating between different density levels, it allows the capture of chemical data from both the internal and external morphology of fossils. This is otherwise difficult to acquire due to the compressive nature of fossilisation. According to wholesaler Block Imaging, medical CT scanners can cost anywhere from $55,000-$275,000 excluding installation or software costs. CT scanning however, is limited to smaller fossils: many dinosaur bones (such as sauropods), and megafauna fossils are too large to fit within the interior of the CT scanner and must be scanned using other means.

Laser scanning provides the ability to create high quality imaging of an objects surface area, using a range of mounted and handheld sizes. The Smithsonian Digitisation team used a combination of handheld laser scanners and mounted, spatial-mapping laser scanners called Digitisers. Laser scanning provides a higher flexibility in what can be scanned and allows macro-precision 3D modelling. According to wholesaler Direct Dimensions, laser scanners and digitisers can cost between $20,000-$120,000, while the software to process the imaging data can cost between $8-$30,000.

Photogrammetry however, is the first truly affordable scanning technology. Using overlapping photographs of a fossil to derive reference points, Photogrammetry can be achieved through the use of an 8 megapixel commercial camera: the same quality as high-priced mobile phones. Photogrammetry uses open source (free), automated software with no training necessary.

Peter Falkingham’s paper on *Acquisition of high resolution three-dimensional models using free, open-source, photogrammetric software*, compares the cost, speed, and quality of 3D models generated with laser scanning and photogrammetry. The comparison of the two methods on a model of a cast bird track determined that photogrammetry had a high quality 3D model, consisting of 1,390,894 vertices(reference points) derived from 75 photographs, compared to the laser scans 96,832 vertices (reference points). Photogrammetry can not only by used for digitising current fossil collections, however. If there are enough photographs from overlapping angles, 3D models can be created from fossils that have been broken or lost.

3D Modelling

In his paper, Faulkingham hopes to aid in facilitating research ... and collaboration through the sharing and dissemination of digital data. With the development of Virtual Paleontology, researchers are no longer limited by the geographic location: 3D models can be copied and sent anywhere in the world; fossils can be more easily cross-referenced with fossils from other collections; and collaboration is more easily achieved. So too, the 3D model could smooth out the render where burial has degraded the quality of the fossil.

Computational analysis of 3D models has the potential to scientifically confirm many theories surrounding dinosaur appearance and movement. Discover Magazine's Ed Young reports on a new approach for estimating the weight of fossil animals developed by Dr Bill Sellers, paleontologist from the University of Manchester. Demonstrating with the *Giraffatitan* skeleton (previously known as the *Brachiosaurus*) displayed in the Berlin Natural History Museum, Sellers laser-scanned the skeleton and used virtual software to wrap the bones in a skin outline. Previous experiments with modern animals showed the resulting weight to be consistently 21% under the actual weight of the animal. With the 21% weight addition, Sellers estimated the *Giraffatitan* to weigh 23,200 kilograms.

Compared with two estimates taken from the June 5, 2014 blog of paleontologist Dr Mike Taylor from the University of Bristol, who estimates at 23,377kg, and paleontologist Roger Benson from University of Oxford at 56,000kg, it is easy to see the difficulty in confirming the weight of fossil skeletons. Despite this, Seller’s estimate is encouraging as it is comparable to modern animals, reproducible, and automated. Ed Young comments, “If it truly works for dinosaurs, we can weigh these extinct beasts as quickly as the laser-scanner can be wheeled around a museum.”

3D Printing

Using 3D printing, 3D models can be extended further than their digital representation. By horizontally slicing a 3D model, each layer can be printed using plastic, to create a physical representation of the model. For dinosaurs such as the *Giraffatitan*, and prehistoric megafauna such as rorqual whales, where their size makes them difficult and time-consuming to analyse, the ability to create a precise, scaled-down model is highly advantageous. The result would be many times lighter than the original, and much easier to mount for an exhibition. For other fossils that are highly delicate and vulnerable to overhandling, or partial skeletons, 3D printing provides a sturdier model to test. Using these substitutes will extend the life of the fossil, without subjecting them to traditional castings.

US paleontologist Dr Kenneth Lacovara from Drexel University is using small-scale 3D printed sauropod bones to test hypotheses on dinosaur behaviour and biomechanics. Using Robotic techniques to create artificial muscles and tendons for the 3D printed sauropods, Lacovara can perform comprehensive tests of how the animal's body could have handled physical stresses of the environment.