

Feature



Digital imaging and public engagement in palaeontology

Public engagement and the promotion of science to a wider non-academic audience form an integral role of the professional scientist in the twenty-first century. The high level of public interest in palaeontology means that the Earth's prehistoric past can provide an important medium through which to communicate information concerning contemporary scientific issues. Here we explain how modern computer techniques can be used to enhance public understanding of complex palaeontological issues.

The fossil record demonstrates clear links between major shifts in global biodiversity and climate change, providing the hindsight to emphasize the need for greater management of the planet in the face of global changes to the environment. The selective processes acting on species through time, elegantly displaying 'descent with modification,' provide palaeontology with the physical evidence that underpins our understanding of life on earth. As quantifiable evidence, fossils make Darwinian evolution more real and relevant to a general audience, and help demonstrate exactly how scientists understand what they do about evolution. The fossil remains of lost worlds and forgotten lives from millions of years ago can be captivating enough to spark a life-long passion for exploring science, and this in itself makes the public engagement in science a critical function for scientists of all disciplines to pursue. The multidisciplinary approaches adopted by many palaeontologists also offer windows into many other subject areas, from particle physics to bioengineering.

However, the added importance of public engagement responsibilities in recent years has been accompanied by an increasingly intense academic review system, coupled with pressure to regularly publish academic articles. With these increased demands on time and resources, a means to synchronize the communication of research to academic and non-academic audiences in an effective way would greatly enhance public awareness of palaeontology as a science. Digital imaging and documentation techniques offer one such means to achieve this feat. The research benefits of digital data collection techniques are by

now probably familiar to most palaeontologists; they are typically fast, accurate, quantitative and above all non-destructive, with techniques such as X-ray Computer Tomography (XRT) allowing the detailed examination of internal architecture and structure of fossils that was only previously possible by serial sectioning culminating in the loss of the specimen. The striking visual presentation achieved through digital methods also provides scientists with the ability to better compare results and subsequently draw more informed conclusions. This similarly means that digital models of fossils can be effectively used to visually communicate what would otherwise be complex or technical information to a non-academic audience. Digital presentations are particularly beneficial in the case of extremely rare, delicate or valuable fossils, as they allow the material to be viewed by the public without the risk of damage or loss during transport and handling. Indeed, it is extremely simple to carry hundreds of 3D digital models of fossils in electronic form, allowing specimens from museum collections around the world to be easily accessed by the public. Digital or 'virtual' fossils can also be used in stand-alone interactive educational displays for museum exhibits or websites, in addition to public engagement events. The electronic 'life' in these fossils is particularly attractive to the generation of computer literate students who start using computer-based learning packages from an early age. The raw material for such interactive packages is often restricted by access to accurate content, something the science could easily provide.

In this feature we detail two case studies in which

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digital data taken from our research that has contributed to public engagement programmes and the use of fossils as an educational resource. Although currently in use, these examples will continually be developed and updated as the research progresses, illustrating the ease with which digital research data can be modified to suit a wider audience. In our second case study the techniques employed offer both valuable information to science and the possibility of such technologies providing visual output critical in the public awareness of geoconservation.

Case one: dinosaur body mass interactive exhibit

In two recent studies our group used laser scanning and computer modelling to construct models of a number of dinosaurs. The purpose of these studies was to estimate the body mass of dinosaurs. A long-range laser (LiDAR) scanner was used to digitize several mounted skeletons, allowing the reconstruction of body volumes and respiratory structures as a 3D model. Following earlier work by John Hutchinson at the Royal Veterinary College (UK) a sensitivity analysis was also carried out, in which a suite of larger and smaller body volumes were reconstructed to help characterize the range of possible mass properties for each dinosaur. Given the absence of soft tissue preservation in most dinosaur fossils, it is not known exactly how large these animals were in life. This approach emphasizes that body mass estimates for extinct species must be stated as plausible ranges rather than values of best estimate reconstructions.

Imaging the full skeleton provided the facility to display the various reconstructed body outlines and internal organs. The explicit communication of the size and shape of the reconstruction then allowed more meaningful comparisons with other models. The eye-catching presentation and popularity of the subject matter make these interactive models ideal for public engagement activities. The models were initially used in a series of science open days at museums and schools as part of a dinosaur biomechanics exhibit. The sessions proved very successful, receiving a significant amount of interest from visitors of all ages (Fig. 1). This success prompted the development of a stand-alone interactive display that could be housed in a museum or on a website.

The display is based on an *Allosaurus* mount known as 'Big Al' and was developed specifically for the University of Wyoming Geological Museum (Wyoming, USA). Big Al (Fig. 2) represents one of the most complete dinosaurs from the Morrison Formation (Wyoming, USA), excavated in 1991 from the eastern Bighorn Basin near the town of Shell. Although the theropod *Allosaurus* has been known for over 100 years, Big Al has one of the most complete



skulls and skeletons of this dinosaur. Big Al is particularly important as it represents a partially articulated, 95 per cent complete, pathologic (with broken, fractured, and infected bones) skeleton of a sub-adult *Allosaurus*. Subsequently this specimen has garnered international recognition through being featured on BBC television's 'Walking with Dinosaurs—*Allosaurus*' documentary.

A mounted cast of the Big Al skeleton constitutes the centrepiece and main attraction at the University of Wyoming Geological Museum. The skeleton is accompanied by a series of text- and image-based (photographs, illustrations) information boards that explore the palaeoecology of this animal and how it may be deduced from the physical evidence displayed in the fossil.

The new interactive display allows visitors to answer for themselves 'How big was Big Al?' by selecting a number of possible body segment masses, according

Fig. 1. Science open day at the Manchester Museum (UK). A digital volumetric model of the *Tyrannosaurus rex* mounted in the museum was used to explain how scientists calculated the mass properties of these animals from just their skeletal remains.

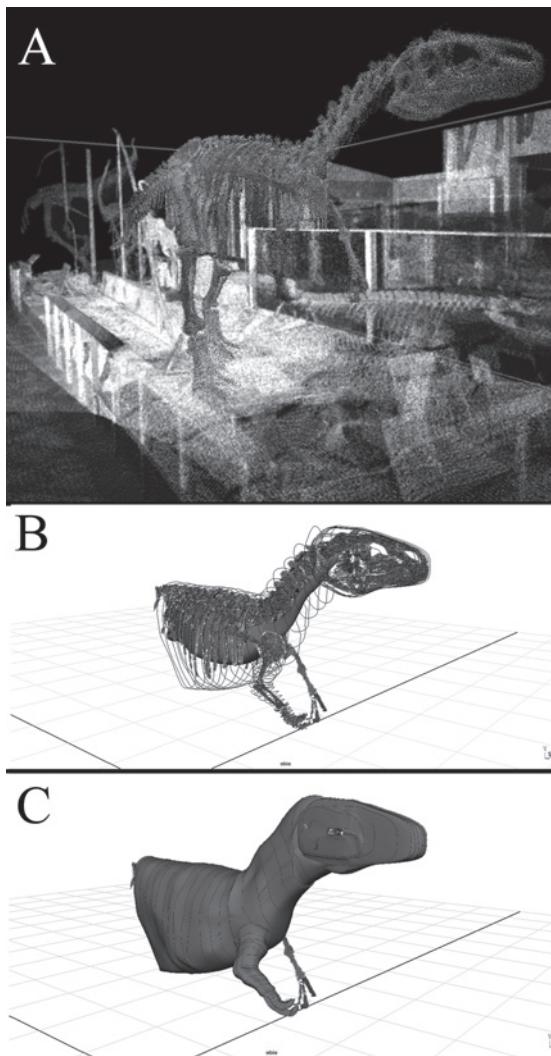


Fig. 2. **A.** Raw LiDAR point cloud of the cast of 'Big Al' (MOR 693) at the University of Wyoming Geological Museum. **B.** Triangulated skeletal model of upper body area, surrounded by Non-Uniform Rational B-Spline (NURBs) circles. **C.** Surface lofted through NURBs circles to produce body volume.

to how they think Big Al would have looked (Fig. 3). The values of our own best estimate reconstructions are provided to allow the user to compare results. Designed with Adobe Flash, the interactive display seamlessly integrates still images, text and animations in a fully interactive manner. The nature of the software allows the application to be operated via a mouse or touch screen control, and is equally useable and effective as a museum gallery exhibit, or via website delivery to personal computers at home. This latter option makes the specimen and information accessible to a wide audience, and may encourage visits to the museum after potential visitors have had a chance to 'interact' with a dinosaur that they can then go and see.

Case two: Roland T. Bird's theropod-sauropod 'chase-sequence'

Fossil trackways exposed in the bed of the Paluxy River at Glen Rose, Texas (USA) are arguably some of

the best preserved in the world, and include the first definitive sauropod tracks recognized. That fact alone has given the tracks significant historical importance, and they attract thousands of visitors to Glen Rose every year. The site was brought to the attention of the scientific community through the expeditions of Roland T. Bird in the late 1930s and 1940s. The most infamous of Bird's discoveries remains his supposed theropod-sauropod chase sequence (Fig. 4). Noting parallel trackways and irregularities in the distribution of footfalls, Bird proposed that a sequence of fossil tracks captured the pursuit of a sauropod by a large carnivorous dinosaur. He considered this sequence so unique and important that it was removed from the Paluxy River site and housed in two separate blocks at the American Museum of Natural History (AMNH) and Texas Memorial Museum (TMM) in Austin. Whether or not these two parallel trackways were contemporaneous and recorded predator-prey interaction is the subject of on-going research, but for now Bird's tale provides a captivating storyline for the public.

Unfortunately, the nature of the fossils (size, weight, etc.) has made it difficult to manage and conserve the track blocks. This has meant their potential as a scientific and educational resource has not been met. The tracks at TMM were excavated as part of a $9\text{ m} \times 3.65\text{ m}$ fragmented limestone slab and were reconstructed on the earthen ground outside the main museum and subsequently enclosed within a single-storey building. Deterioration of the TMM trackway was first reported in 1988. The University of Texas Conservation Lab released a detailed report on the condition of the tracks and made recommendations for their care in 1993.

The deterioration, resulting in a loss of surface detail, has several sources. Moisture and soluble salts evaporating up from underlying soil were trapped by a coating of paint that was applied to the track surface during its consolidation in the building. The salts broke down the stone from the inside out and the trapped moisture eventually lifted off the paint and the limestone attached to it. Coupled with a leaking roof, windows and inadequate ventilation a humid environment ideal for the growth of stone damaging moulds developed. Between 1988 and 2008 the condition of the tracks did not improve and today they continue to deteriorate. As of November 2008 a stone conservation specialist has been contracted to test the condition of the tracks and a report is due in 2009. Given the public has never really seen or understood the significance of the tracks there was little public pressure to improve their conservation. The TMM administration regarded the tracks as 'an educational resource' but one whose potential was difficult to realize.

In the summer of 2008, the track blocks at the

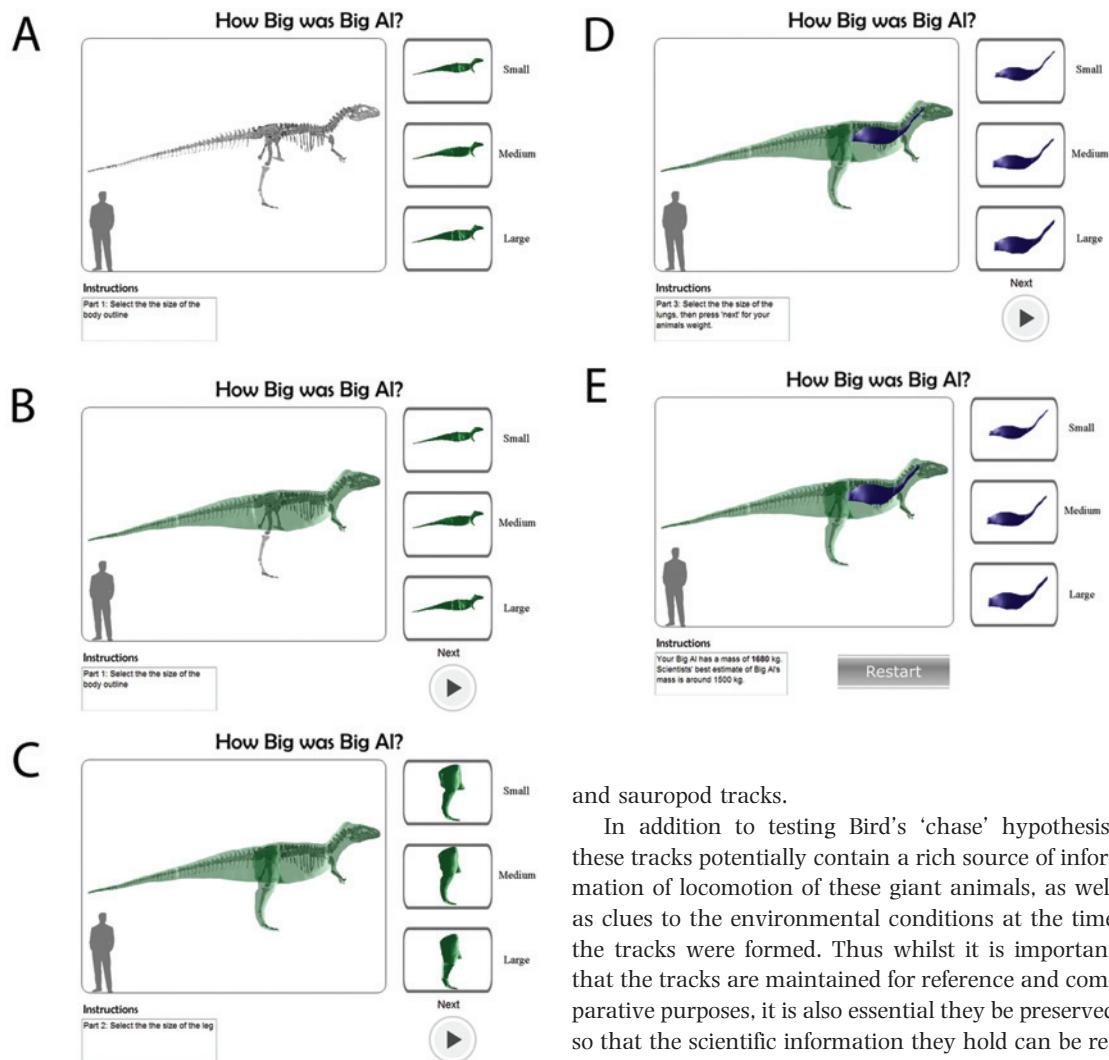


Fig. 3. The 'How big was Big Al?' interactive body mass display, made in Adobe Flash. In a succession of screens the user is able to select from a range of different sized body, leg and respiratory volumes and until they have completely reconstructed Big Al. Each segment has a mass attached (using data from our own scientific publications) and the final screen reveals the body mass of Big Al based on their particular combination of chosen segment volumes.

AMNH and TMM were digitized using the same method (LiDAR) employed to image the mounted skeletons. If the conservation of the track blocks at TMM is not successful, then these scans will serve as the only 3D record of these important tracks. Given that the Paluxy tracks represent the best-preserved sauropod tracks in the world and have type status for the trace fossil *Brontopodus birdi* it is important they are accurately recorded. As the representative type specimen the AMNH and TMM slabs are the standard for this trace fossil morphology and it is imperative that it be preserved so that palaeontologists will have continued access to it for future research. The motivation for digitization of the trackway was primarily scientific; the data will constitute components of two separate doctoral dissertations being carried out at the University of Manchester by two of the authors. These projects will attempt to use state-of-the-art computational techniques to address questions relating to the locomotor dynamics of the track-makers and the formation and preservation of the theropod

and sauropod tracks.

In addition to testing Bird's 'chase' hypothesis, these tracks potentially contain a rich source of information of locomotion of these giant animals, as well as clues to the environmental conditions at the time the tracks were formed. Thus whilst it is important that the tracks are maintained for reference and comparative purposes, it is also essential they be preserved so that the scientific information they hold can be re-evaluated as new methods and analytical techniques become accessible. If re-housed in a gallery-like environment not only would the tracks be more easily managed and accessible to the visiting public but they could be combined with a stand-alone interactive display, maximising their potential as an educational resource, emphasising their scientific value.

As in the previous case study, the chase sequence data has been used in recent public engagement events, using the in-house software Virtual Reality Geological Studio (VRGS). VRGS was written to provide a platform for the integration and manipulation of quantitative digital outcrop data (e.g. LIDAR) and conventional field-work approaches (e.g. facies analysis and logging). VRGS currently contains a suite of tools for extracting geostatistical data from digital outcrop models, including planar measurements (e.g. bedding or fault plane strike and dip), linear measurements (e.g. bedding thickness, fault displacement), 3D volumes and surface areas, in addition to other geological mapping functions. The VRGS toolkit also includes a variety of functions specifically designed



Fig. 4. R.T. Bird's 'chase sequence', in which a carnivorous theropod (bipedal trackway, left), possibly *Acrocanthosaurus*, was thought to be following an herbivorous sauropod (quadrupedal trackway, right). Both trackways bend to the length over their course, and the theropod repeatedly stepped in and deformed the prints of the sauropod.

for rapid interrogation of digital models of vertebrate tracks and trackways. Surfaces generated through the point clouds in VRGS can be colour-coded to highlight fine-scale relief features and models can be magnified and rotated, to be viewed from any perspective. Track and trackway measurements are automatically data-based internally within VRGS (Fig. 5), which also contains automated functions such as the calculation of trackmaker speed from track length and stride length according to the mathematical relationship described by McNeill Alexander.

Displayed in VRGS, the digital model of Bird's chase sequence has replaced a roll-out paper trackway display formerly used to convey the information that can be extracted about dinosaurs from their tracks. Whilst successful in the past, the old paper display required a significant amount of space and had to be regularly replaced after being torn by over-enthusiastic members of the public keen to walk in the footsteps of the trackmaker. Like the body mass exhibit, the new digital track display has proven extremely effective because it allows the visitor to go through a process of scientific discovery, literally step-by-step learning how fast the predator may have been chasing its prey.

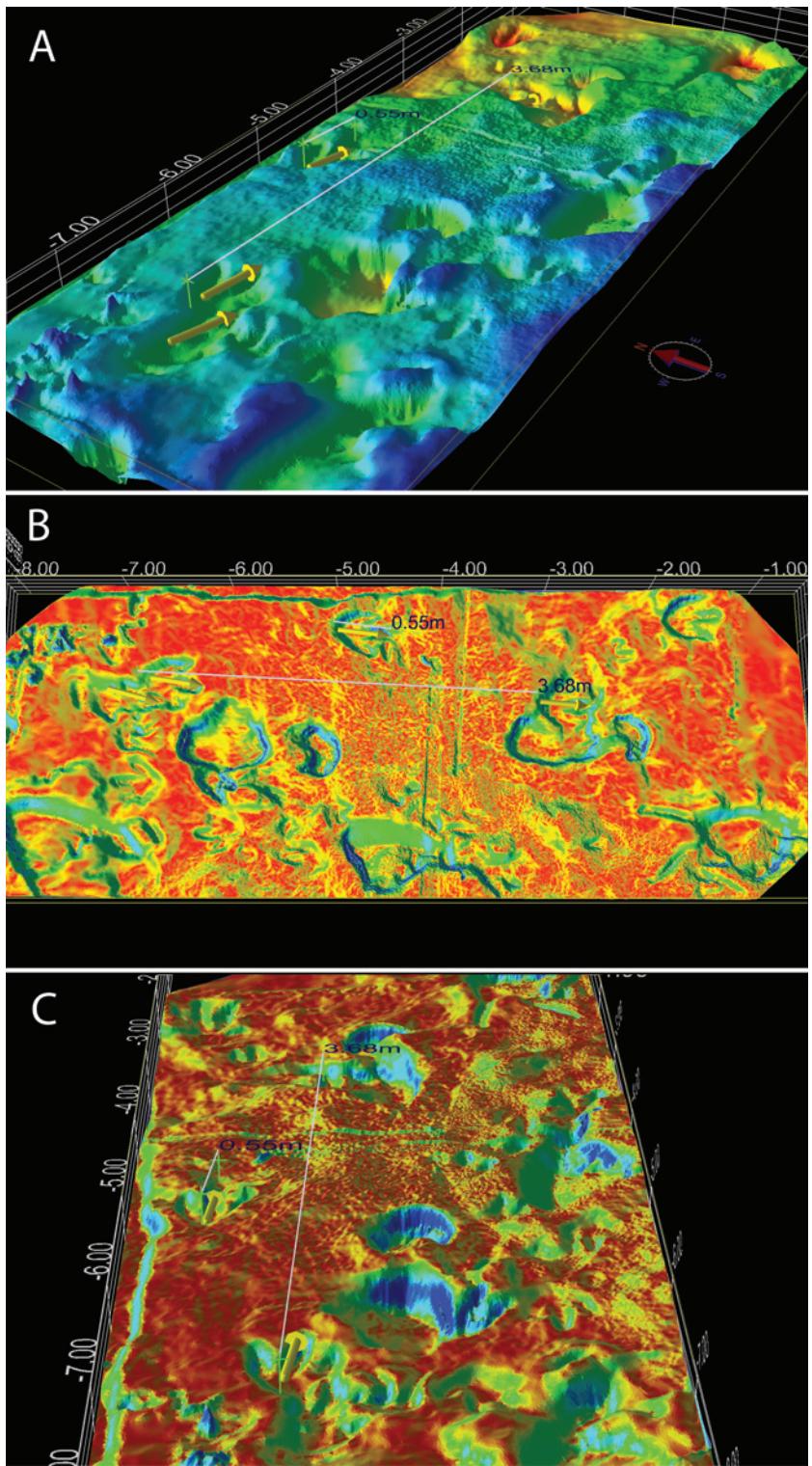


Fig. 5. LiDAR scans of the Texas Memorial portion of Bird's theropod-sauropod chase sequence, with selected foot length and stride length measurements shown. In VRGS the model's surface can be presented in a variety of formats to highlight various features in the tracks, including being colour-coded according to: **A**, depth; **B**, dip angle and **C**, curvature.

The display is currently not stand-alone as VRGS requires operational guidance and at this time is not commercially available. However, the long term goal is a stand-alone display communicating the new data generated about these unique tracks and the fascinating animals that made them.

Concluding remarks

Digital technologies are making increasingly important contributions to our understanding of fossils animals, providing new and exciting answers to very old questions. It is hoped that the examples outlined here demonstrates that the utility of digital techniques also extends to wider practices in science, emphasising that virtual fossils have an important role to play in the promotion, management and conservation of palaeontological science in the twenty-first century.

Acknowledgements

This research was funded by doctoral dissertation grants from the National Environmental Research Council (UK) to K.T.B. (NER/S/A/2006/14101) and P.L.F. (NER/S/A/2006/14033), with additional funding to K.T.B. from the Jurassic Foundation and the Pal-

aeontological Association Sylvester-Bradley Award. We thank John Maisano and Ed Theriot (TMM) and Carl Mehling (AHMN) for providing generous access to the Bird chase sequence slabs.

Suggestions for further reading

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