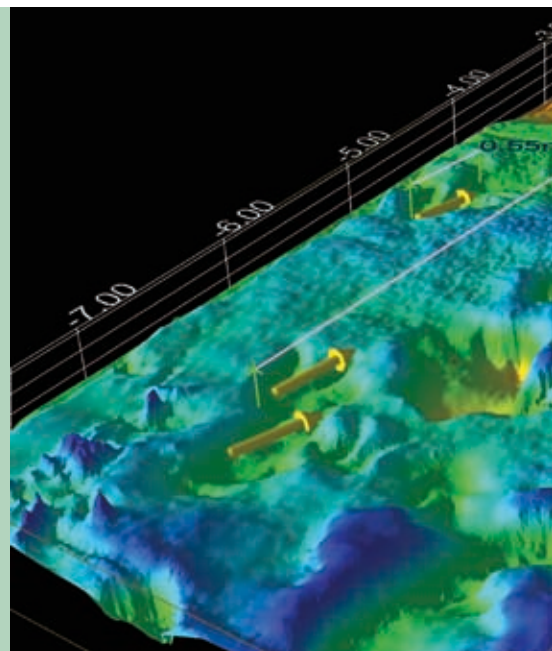


Walking with dinosaurs

Peter L. Falkingham is one of a new breed of palaeontologist whose computational techniques look set to revolutionise our understanding of how dinosaurs and other extinct animals behaved.



The media image of palaeontology is often of field workers camped in the desert in the hot sun, carefully picking away at the rock surrounding a large dinosaur bone. But I've not done that for a while now. Instead, much of my time is spent at a computer. Not because I have become inundated with paperwork, but because I am a new kind of palaeontologist: a computational palaeontologist.

What few people may consider is that uncovering a skeleton, or discovering a new species, is where the research begins, not where it ends. To know what life existed at a given moment in geological time is only part of the picture. What we really want to understand is how the extinct animals and plants behaved in their natural habitats. What did they look like? How did they move? Why aren't they alive today?

This is my core approach to palaeontology. I am part of a new generation of palaeontologists who are bringing a

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modern tool to bear – the computer – on some of these old questions. We are using computer simulation and modelling to study ancient life. From looking at the stresses in a *T. rex* skull when it bites, to digitally picking apart the internal anatomy of early arthropods, to using CT scanners to peer inside archaeopteryx's skull and reconstruct its hearing,* the computer age has finally met with the ancient world.

Drs Bill Sellers and Phil Manning from the University of Manchester, for example, use a 'genetic algorithm' – a kind of computer code that can change itself and 'evolve' – to explore how extinct animals like dinosaurs, and our own early ancestors, walked and stalked.

The computer model is given a digitised skeleton, and the locations of known muscles. The model then randomly activates the muscles. This, perhaps unsurprisingly, results almost without fail in the animal falling on its face. So the computer alters the activation pattern and tries again... usually to similar effect.

The modelled 'dinosaurs' quickly 'evolve'. If there is any improvement, the computer discards the old pattern and adopts the new one as the base for alteration. Eventually, the activation pattern evolves a stable gait, the best possible solution is reached, and our dinosaur can walk, run, chase or graze. Assuming natural selection evolves the best possible solution too, the modelled animal should be moving in a manner akin to its real-life counterpart. And indeed, using the same method for living animals (humans, emu and ostriches) we achieved similar top speeds and gaits as in reality.

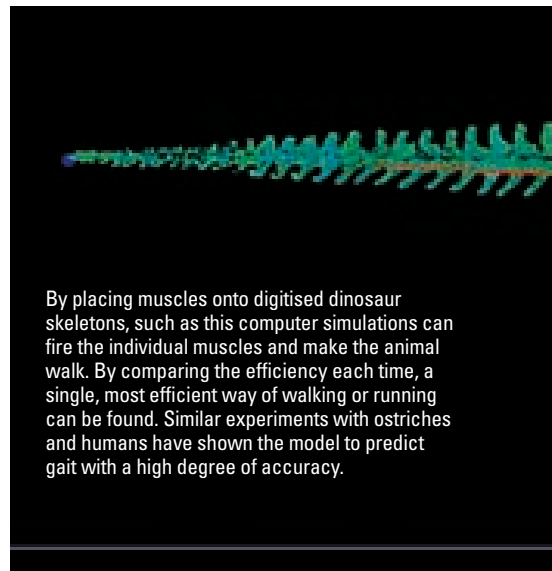
I am investigating fossilised tracks, or footprints, using computer simulations. Tracks are (to some) one of the most exciting pieces of evidence as to how ancient animals lived, from their biology to ecology. Talk to a modern-day tracker, and they can tell you what animal made a track, whether that animal was walking or running, sometimes even the sex of the animal. But a fossil track poses a more considerable

challenge to interpret in the same way.

We can video living animals moving, but how did dinosaurs or other extinct animals move? Another crucial consideration is knowing what the environment and the mud, or sediment, upon which they walked was like millions of years ago when the track was made.

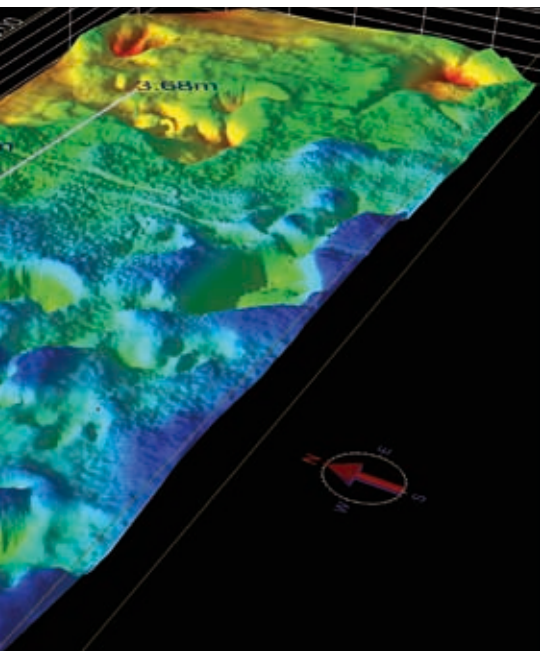
We need to run experiments to answer these questions, but the number of variables is staggering. To physically recreate each scenario with a box of mud is extremely time-consuming and difficult to repeat accurately. This is where computer simulation comes in.

By using computational techniques, we can model a volume of mud and control the moisture content, consistency and other conditions. A virtual foot can then be made to step on the digital surface of the mud to make a footprint. We can then chop up this footprint and view it from any angle, we can



By placing muscles onto digitised dinosaur skeletons, such as this computer simulations can fire the individual muscles and make the animal walk. By comparing the efficiency each time, a single, most efficient way of walking or running can be found. Similar experiments with ostriches and humans have shown the model to predict gait with a high degree of accuracy.

*The University of Bristol, Imperial College London, and the Natural History Museum respectively.



This series of tracks from Glen Rose, Texas, has been previously interpreted as a 'chase sequence', where a carnivorous dinosaur has followed a large plant-eating sauropod. By creating a digital model of the tracks with high-resolution laser scanning, the surface can be colour coded according to height. This highlights tracks more clearly than in the field, and allows us to see which footprints came first. The scan supports the idea that the predator came after the prey.

footprint was very different – it was webbed. The virtual soil had been pushed up between the toes, before collapsing into a platform-like structure – a structure that in a fossil track would be interpreted as the impression of a webbed foot.

This has wider-ranging implications than you might think. You see, webbing between toes, such as that found on a duck's feet, is soft tissue, and as you may realise, soft parts of animals only rarely get preserved as fossils. So, much of our evidence for the evolutionary history of birds with webbed feet comes from tracks.

But here was a specific sedimentary scenario where a webbed track could be made by a non-webbed foot. So have previous assumptions about the lineage of webbed feet been wrong? Possibly. The results of this experiment call for careful interpretation and reinterpretation of webbed footprints. Perhaps web-footed birds were not as geographically widespread during the Cretaceous as had been previously thought. This will probably spur more research in this area.

Our computer simulations are not that far removed from traditional palaeontology. Fossil hunters are increasingly using laser scanning. Several research groups around the world, including ours at the University of Manchester, are employing long-range laser scanners to digitally record outcrops. In our case, much of the laser-scanning work

has been carried out at dinosaur track sites across the globe.

The technology is quite amazing. When we set up a scanner, after only a few moments we can see the surrounding 800m on our screen in 3D with an accuracy of half a centimetre. This makes studying tracks located on a cliff face considerably easier, safer and quicker, albeit perhaps a tad less exciting. Subsequent scans of the same site allow us to measure weathering rates, and keep a record of tracks and fossils that will one day sadly erode away.

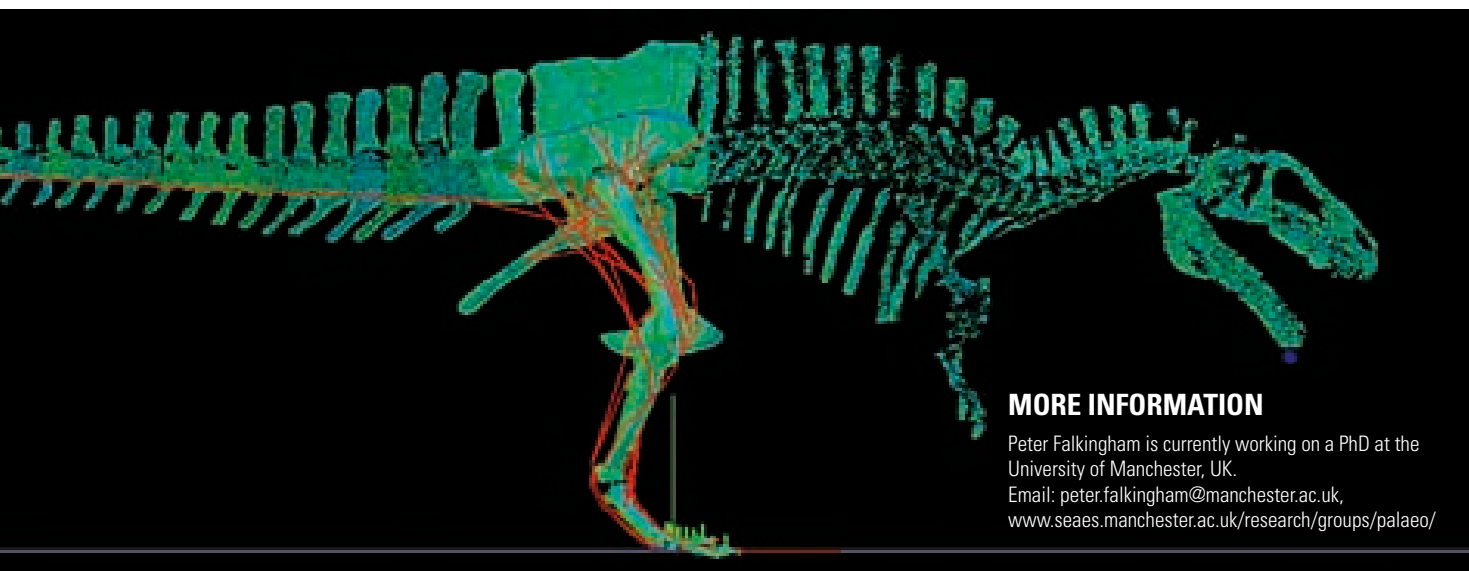
Researchers at the University of Oxford have used the same laser-scanning technique to record the enigmatic Ediacaran fossils. These fossils are evidence of the earliest known complex life. To the untrained eye they appear to be little more than a strange, low-relief texture on a rock surface, but by scanning to sub-millimetre resolution, the digital models can be lit with low angle light, or vertically exaggerated to make otherwise inconspicuous features stand out, helping palaeontologists figure out just what these organisms were.

The application of computational techniques in palaeontology is becoming more prevalent every year, as researchers discover new ways to apply methods from fields such as engineering and mathematics to the study of ancient life. Being able to discuss work with colleagues by emailing digital copies of fossils has revolutionised international collaboration, and provides a means of communicating discoveries to the public via the web, allowing virtual tours of fossil sites without risk of damage. What's more, as computer power continues to increase, the range of problems that can be tackled and questions we can answer will only expand. ♦

even extract values of stress and strain inside the footprint.

By running hundreds of simulations simultaneously on supercomputers, we can start to understand what types of footprint would be expected if an animal moved in a certain way over a given type of ground, known in the jargon as substrate. Looking at the variation in the virtual tracks, we can interpret fossil tracks with greater confidence.

Sometimes the experiments can throw up unexpected results – the best kind! One such instance came when simulating a wet, sloppy mud (an experiment definitely cleaner in the virtual realm). I was trying to work out how an extinct bird walked, and subsequently what this meant for walking throughout the evolution of dinosaurs to birds. As with dozens of prior experiments, I was pushing my three-toed foot into my virtual soil. This time, though, the resulting



MORE INFORMATION

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