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PAUL SOUDERS/COREIS

The terracotta army, which consists of individually sculpted warriors, was found inside the mausoleum of China's first emperor, Qin Shi Huang.

ARCHAEOLOGY

3D images remodel history

Digital-photo software promises to offer unprecedented access to artefacts and sites.

BY EWEN CALLAWAY

It took hundreds of thousands of workers decades to create China's terracotta army, but digital avatars made in minutes could solve the lingering mystery of one of the country's most famous relics. By creating three-dimensional (3D) models of the 2,200-year-old collection of statues, archaeologists hope to confirm whether the soldiers were intended to represent a real army of distinct individuals.

Known broadly as computer vision, the

technology was developed to enable machines such as factory robots and the Mars rovers to map a 3D world from camera images. But now it is quietly revolutionizing archaeology and palaeontology, allowing virtual bones, artefacts and whole excavation sites to be shared and studied without risk of damage.

"In the future, it's highly likely that these sorts of methods will be the standard thing you do to record an archaeological site," says Andrew Bevan, an archaeologist at University College London, who is part of a team using

computer vision to build digital models of the terracotta army's life-size warriors.

Since the army was discovered in 1974 in an emperor's mausoleum near Xian, historians have debated whether the soldiers' facial details were modelled on actual militiamen. "Are the warriors portraits of individual people? Or are they a 'Mr Potato Head' approach to individualism, where you slap on different noses and moustaches and ears?" Bevan says.

Computer-vision models might offer the answer, Bevan suggests. Digital photos ►

► can be taken quickly, cheaply and without disturbing the statues. Several dozen high-quality photos of a soldier, taken from multiple perspectives, can provide a computer algorithm with enough data to determine where each image was taken from and create a 3D map in a few minutes. The model — a set of *x*, *y* and *z* coordinates — can be plotted against other models, analysed and even used to make a cast with a 3D printer.

In a pilot study published on 4 June, Bevan's team modelled the faces of 30 warriors and found that no two ears were identical — evidence that the army consists of individuals (A. Bevan *et al.* *J. Archaeol. Sci.* <http://doi.org/s7v>; 2014). The researchers compared ears because these are unique and may have been modelled on real people. But they plan to analyse other anatomical features to see whether the soldiers vary in ethnicity or bear the hallmarks of distinct craftsmen. Bevan stresses that the work is at an early stage.

Archaeologists and palaeontologists have used computer modelling for decades, to map digs with laser scanners or study bones with computed tomography (CT), for example. But proponents of computer vision argue that these technologies are costly and not made for routine use in the field.

"You're talking about having a camera versus having a £30,000 [US\$50,000] piece of kit ready," says Sarah Duffy, an archaeologist at the University of York, UK. When

"We can expect to see entire collections of hundreds of thousands of objects digitally available."

Superimposed 3D models (one in green, the other in white) reveal minute differences in ear shape.

900,000-year-old footprints were found on eastern England's Norfolk coast last year, she was part of a team that raced to photograph the scene and capture the footprints in 3D. The resulting model revealed that they had been left by a human ancestor — the oldest such relics discovered outside Africa (N. Ashton *et al.* *PLoS ONE* <http://doi.org/rd2>; 2014). The prints had nearly vanished by the time the researchers lugged a laser scanner to the site a week later.

Benjamin Dücke at the German Archaeological Institute in Berlin agrees that the technology has the potential to preserve sites that are disappearing. Last October, he used a drone equipped with a video camera to create a 3D map of a large pre-Columbian settlement in Mexico in a couple of days. His team, called Project Archaeocopter, plans to analyse sites in Uzbekistan and at Pompeii in Italy. With an infrared camera mounted on a drone, the technology could map archaeological sites obscured by dense forests, he says.

Powerful computer-vision software is affordable and readily available, but advocates such as Heinrich Mallison, a palaeontologist

at Berlin's Natural History Museum, see the technology as more than a time and money saver. "It means we can expect to see entire collections of hundreds of thousands of objects digitally available in a decade, so everybody can use these for research," he says. Dücke thinks that the technology has the potential to break the "interpretative monopoly" of scholars whose theories prevail because others lack access to particular artefacts or remains.

Jean-Jacques Hublin, a palaeoanthropologist at the Max Planck Institute for Evolutionary Anthropology in Leipzig, Germany, expects museums to limit the creation and distribution of such models in their collections, in the same way as some have done for CT scans. Museums worry about losing control over their collections, but Hublin thinks that demand among scientists will inevitably push more collections online. With computer-vision technology in mind, in May the European Union began accepting applications for a €14-million (\$19-million) fund to create 3D models of examples of Europe's cultural heritage.

But data theft is a worry, Mallison says. "I can go to a museum in Beijing, pull out my Canon, play tourist and do research on a high-resolution 3D model of their fossils." Academics might not risk the backlash of collecting data without permission, but replica sellers could pillage museum collections with computer-vision software, says Mallison. He thinks that international rules are needed to prevent this. Nevertheless, he predicts that it is only a matter of time before 3D models of museum collections are widely available. "The question is, do we see it in 5 years or 10 years or 15 years?" he says. ■

A. BEVAN ET AL. / J. ARCHAEOLOGICAL SCI. <http://doi.org/s7v> (2014) CC BY

ECOLOGY

Tree hitched a ride to island

Acacia analysis reveals globetrotting seed trekked 18,000 kilometres from Hawaii to Réunion.

BY EMMA MARRIS

In what is probably the farthest single dispersal event ever recorded, researchers have shown using genetic analysis that an acacia tree endemic to Réunion Island in the Indian Ocean is directly descended from a common Hawaiian tree known as the koa. In fact, these two trees on small specks of land on opposite sides of the globe turn out to be the same species.

The event is remarkable not just for the sheer distance covered — some 18,000 kilometres, almost the farthest apart that any two points on land can be — but that it occurred between two small islands. Koa seeds are unlikely to have

floated to Réunion — they will not germinate after being soaked in seawater, and the trees grow in the mountains, not near the shore. The researchers, led by Johannes Le Roux, a molecular ecologist at Stellenbosch University in Matieland, South Africa, propose in a study published this week that a sea bird brought a seed from Hawaii to Réunion in its stomach or stuck to its feet in a one-off event some 1.4 million years ago (J. J. Le Roux *et al.* *New Phytol.* <http://dx.doi.org/10.1111/nph.12900>; 2014).

Le Roux notes that the physical similarities between the two trees, *Acacia heterophylla* from Réunion and *Acacia koa* from Hawaii, have been known for decades. "To me the most exciting thing is that we have solved this

riddle," he says. "And how improbable is it?"

Le Roux and his team sequenced the DNA from 88 trees, including *A. heterophylla*, *A. koa* and a closely related acacia species from Australia, where the family originated. They found that all the acacias on Réunion share a genetic signature that is just one mutational step away from that of some Hawaiian koas. Using the slight differences between the trees' sequences, they developed a family tree, which clearly showed that all *A. heterophylla* are more closely related to one type of Hawaiian koa than some other types of koa are to each other.

To work out when the dispersal event took place, the team used a 'molecular clock'. This counts up genetic changes between populations