3D measurement of osteological remains using fringe projection

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Summary:

The proliferation of non-contact optical 3D measurement systems in industry for performing quality control and dimensional measurements has led to a commercial and academic race to make them more accurate and precise, with shorter measurement cycles. The aim is to one day replace commonly used contact coordinate measurement machines (CMMs), which are accurate but very slow and cumbersome to setup and operate. This trend will have profound effects for 3D digitization of cultural heritage as the level of detail and accuracy of replication of the scanned object continues to rise.

The advantage of the method being non-contact is fundamental as most archaeological and cultural artefacts are sensitive and brittle. Additionally, in most cases the scan can be performed behind a glass layer so there is no risk to removing sensitive artefacts from their protective atmospheres to the elements, which can risk further degradation.

Fringe projection system being developed

At the University of Nottingham we use a method of 3D measurement called fringe projection (FP), used initially for inspecting additive manufactured objects within our research group, but applicable to any object with a highly diffusive and reflective surface. FP works by projecting a periodically repeating pattern of bright and dark fringes onto the object and phase shifting the fringes so that a phase map related to the height of each point on the object can be created. Osteological remains are normally highly reflective and diffusely scattering and hence readily lend themselves for being measured using FP. We believe that the information-rich metrology approach pursued by our group (whereby all prior information available on the object measured is included in the measurement process) will eventually provide the ability to perform 'one-shot' complete object 3D measurement that will further benefit the digital cultural preservation community as rapid accurate measurement will become a reality with a press of a button. A 3D CAD impression of the 'one shot' system being developed is shown in Figure 1.

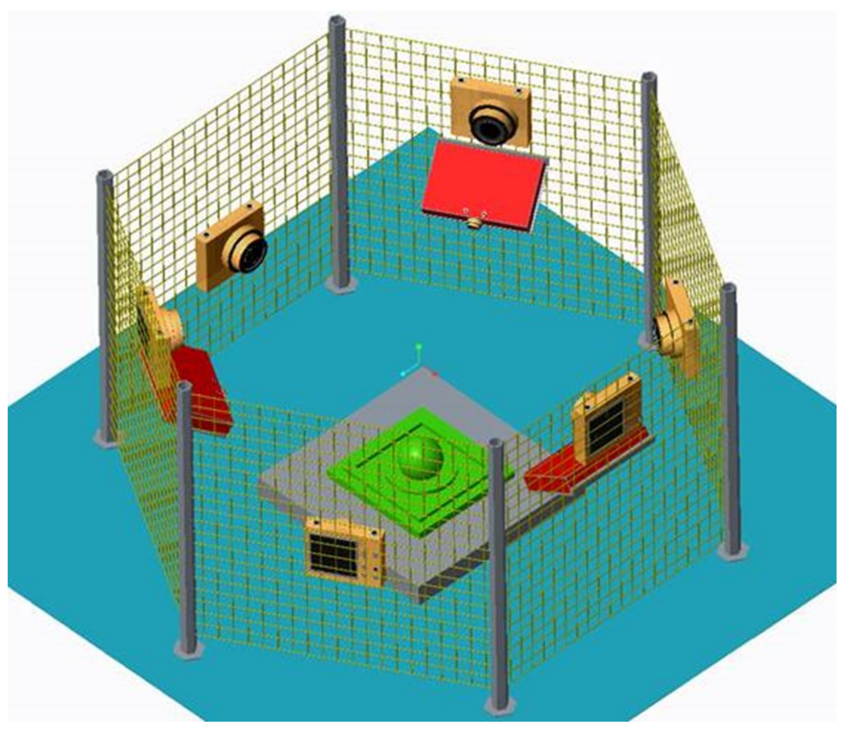
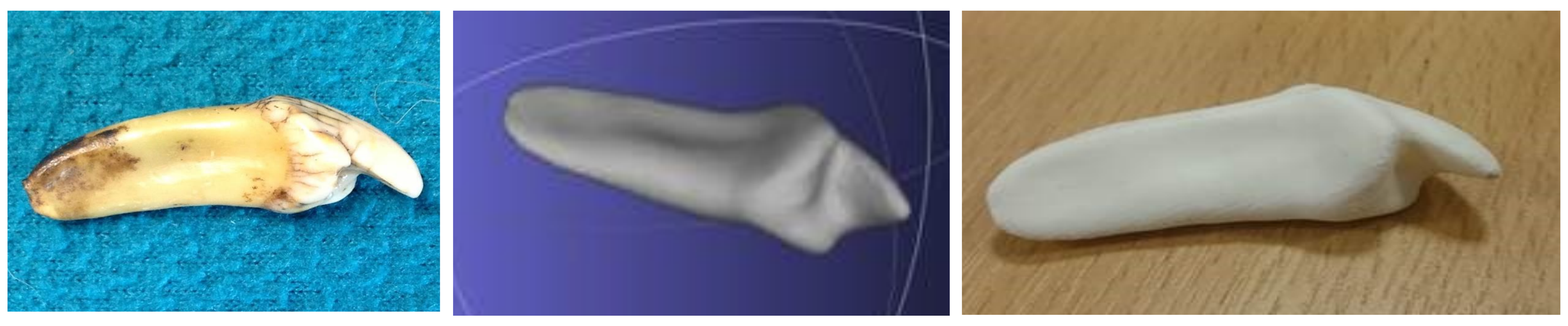


Figure 1. Artist's impression of the 'one-shot' 3D scanning system being developed.

3D measurement of an Ursus arctos incisor

An upper incisor (tooth) from a brown bear (*Ursus arctos*) was found during the excavation of Reynard's Kitchen Cave, in Dovedale, Derbyshire in 2013. Also found within the cave was an Iron-Age to Romano-British coin hoard and artefacts that dated from (possibly) the Palaeolithic onwards. The find of a bear was intriguing and we wanted to find out when bears were using the cave. To do this we needed to do radiocarbon dating. Much of archaeological sampling is necessarily destructive, so to record the tooth as thoroughly as possible before it was sampled, we measured it in 3D with a Sidio FP system from NUB3D in a collaboration between the Archaeology Department and the Manufacturing Metrology Team. Once measured, the tooth was 3D printed, preserving a replica of the unsampled tooth for future researchers.

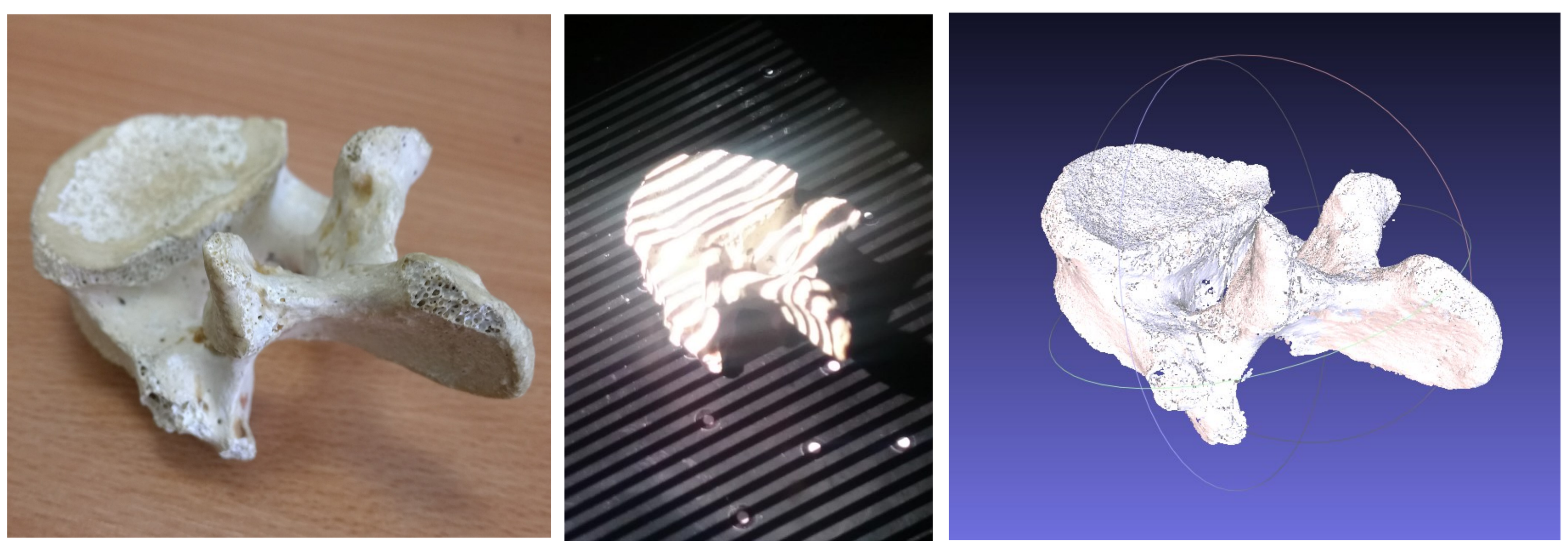


(a) (b) (c)

Figure 2. From left to right (a) bear tooth photo (b) resulting 3D measurement (c) 3D printed tooth.

3D measurement of a human lumbar vertebra

A lower spine human vertebra was measured to prove that the complexity of such bones can be successfully digitized in 3D. The surface was also easy for the FP system to work with and it was successfully measured. Below there is an image of the bone on its own (Figure 3a), the bone while it was being measured via FP in our lab (Figure 3b), and the resulting 3D point cloud (Figure 3c).



(a) (b) (c)

Figure 3. From left to right (a) photo of lumbar vertebra (b) photo whlist being scanned (c) resulting 3D data.

Discussion

As it has been shown from the trials we made, FP is a very useful tool for the preservation and study of osteological remains, both for animal and human bone tissue. The bone material in general has shown to have ideal reflectance properties for FP. The advances which our group is planning to perform on the process of FP (i.e. the development of a 'one-shot' rapid 3D measurement system) which are currently developed primarily for industrial and 3D printing applications will have profound effects on the speed of digital preservation of bones, as well as other materials, such as marble and clay. Effortless and complete measurement of archaeological artefacts of a site opens up new possibilities in the way these objects are studied and sites are investigated.

References

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