Creating High Quality Three-Dimensional Models through Photogrammetry

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Introduction

In recent years, three dimentional models have seen an increased use in the field of paleontology. Models have become increasingly useful because it cannot deteriorate, it is easier to transport to other institutions than the actual specimens and they can be used in studies such as geometric morphometrics. While there are multiple methods of generating these models, most tend to be highly expensive such as CT scanning. One method of generating accurate models of bones and fossils that is relatively cheap is the method of photogrammetry. Photogrammetry is the process that involves taking multiple photographs of an object and then generating a 3D model with the necessary software. The purpose of this study was to develop an effective methodology for model generation through photogrammetry so that it can be used effectively in future research.

Methods

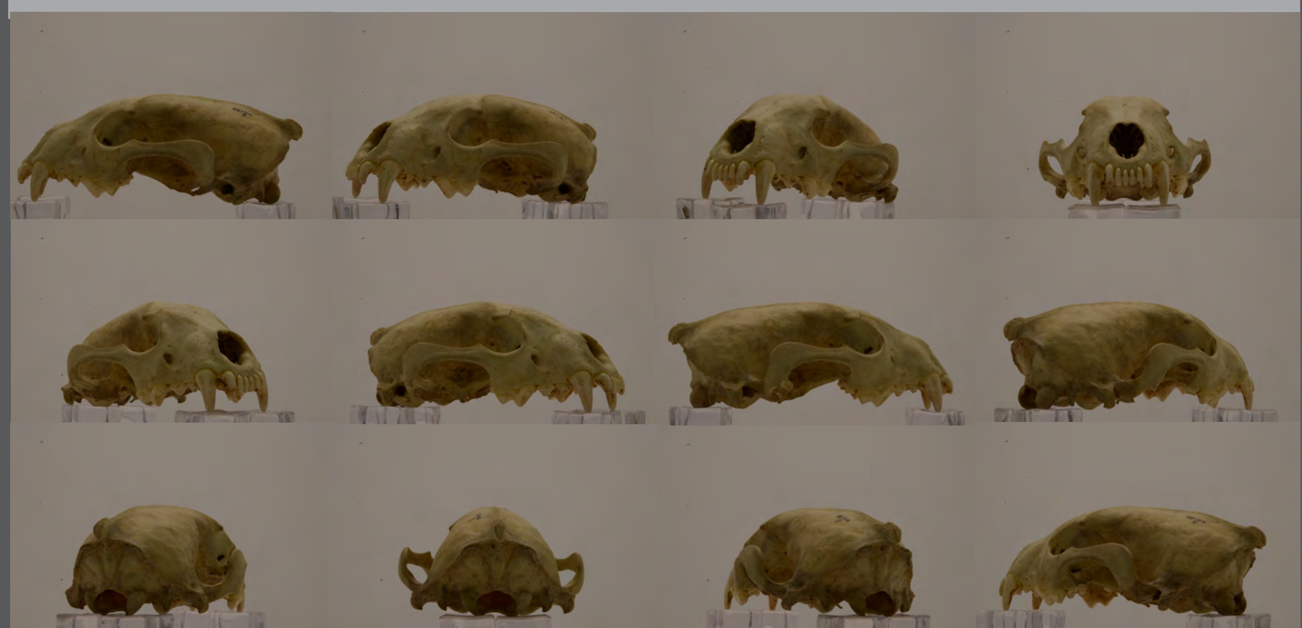

Figure 1 A photo session showing a single rotation of a skull of *Gulo gulo* (UMMZ 98100).

A bone of a mammalian specimen or fossil was selected and placed on a turntable in a photography box, where it was photgraphed multiple times while being rotated. Photographs were saved via digiCamControl and transfered to the Reality Capture software. Once in this software, a dense point cloud was generated from the photographs and then used to generate a model. The model was scaled and extra vertices removed using MeshLab, while articulation and smoothing were accomplished using Blender. A variety of variables were tested to discover the best photography options that produced accurate models of the bones or fossils. Some of these factors include lighting, angle of rotation on the turntable, specimen position and placement, specimen size and shape, and photo quantity (to name a few).

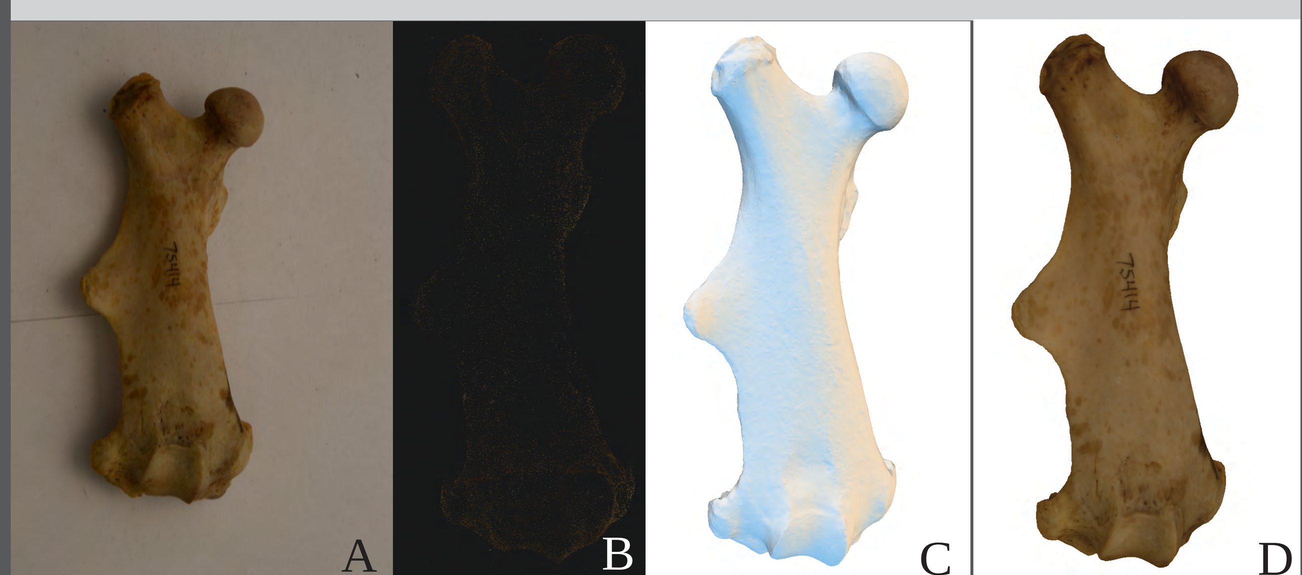

Figure 2 The process of generating a model from photograph (A), point cloud (B), uncolored model (C), and colored model (D). Specimen is a femur belonging to *Castor canadensis* (UMMZ 75414).

Results

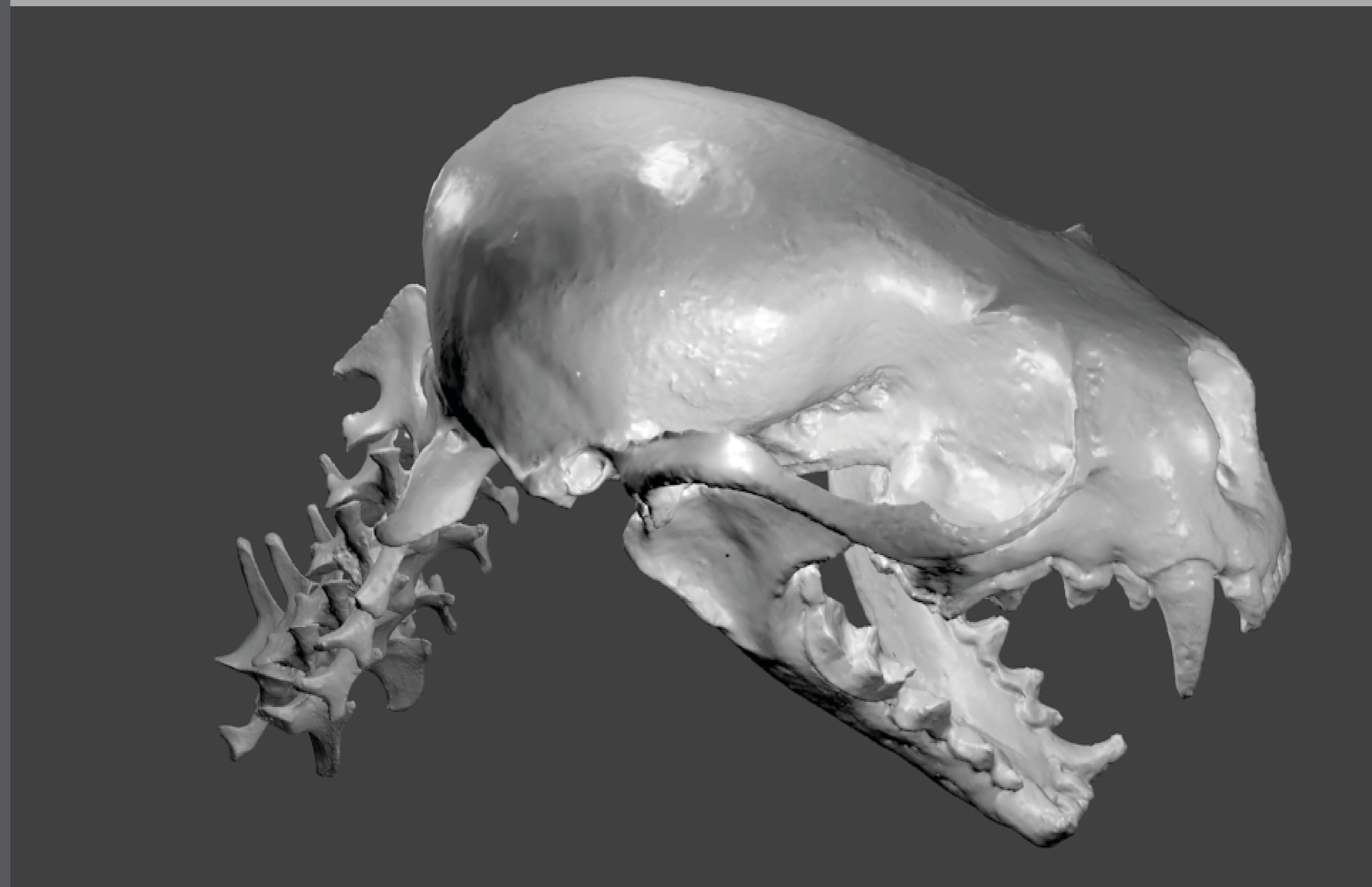

Figure 3 A 3D reconstruction of the skull, jaw and cervical vertebrae of *Lontra canadensis* (UMMZ 84067). Each bone was individually photographed and digitized. The models were then scaled using MeshLab and uploaded to Blender, where they were articulated. The models could also be animated to allow for realistic anatomical movement.

Figure 4 Comparisons of actual specimens to their respective models to show the accuracy of the models generated. Photographs of the specimens are to the left while thier models are to the right. Photograph of the first lumbar of *Lontra canadensis* (A, UMMZ 84067) and its generated model (B). Photograph of a skull of *Lynx rufus* (C, UMMZ 55154) and its generated model (D). Photograph of the upper left molar of *Mammut americanum* (E) and its generated model (F).

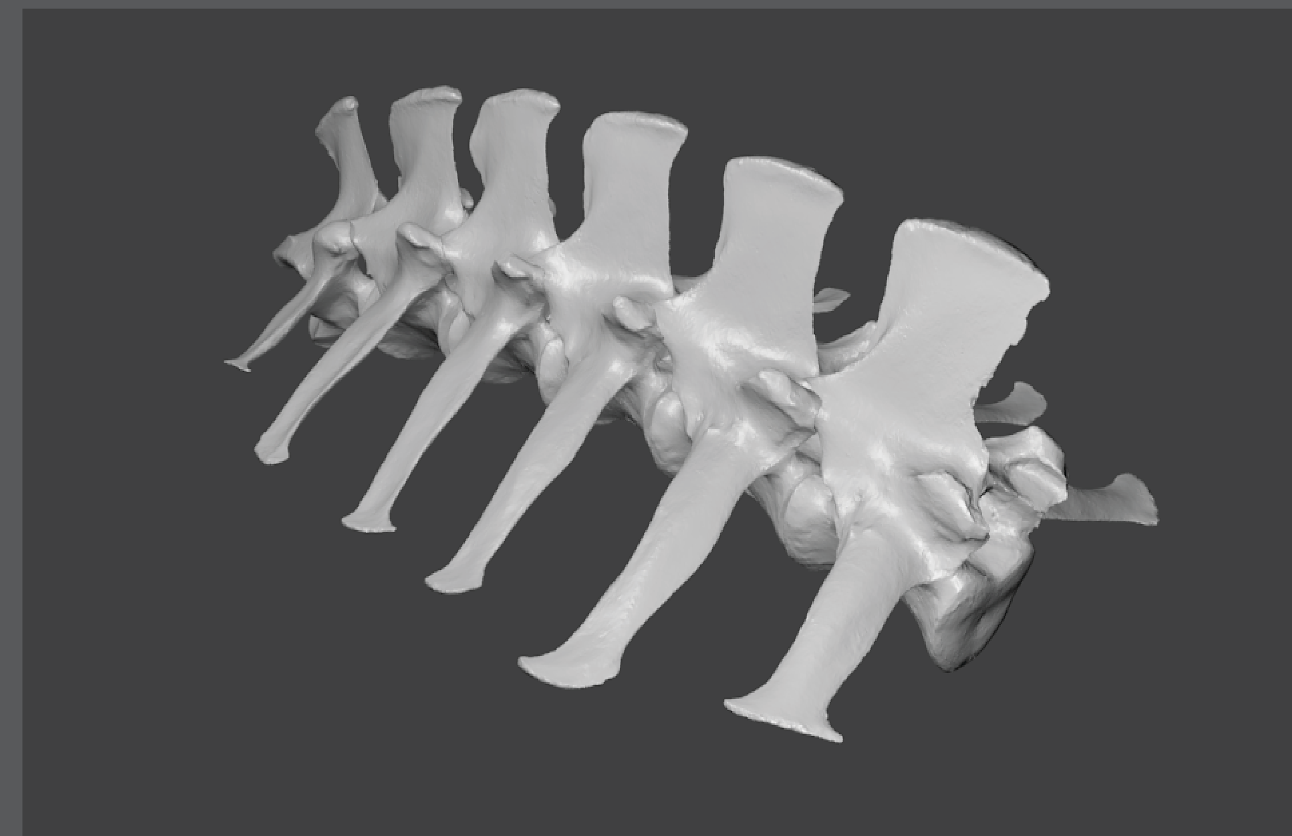

Figure 5 A 3D recontruction and articulation of the lumbar series of *Antilocapra americana* (UMMZ 64148). Vertebrae were individually photographed and digitized. Models were then articulated.

Conclusion/Discussion

Overall, model generation has been successful. Some of the variables that produce the best results include the light source being directly above the photo box, the specimen only needing to be photographed at two views, using acrylic cubes to support lighter specimens and three rotations at different heights per specimen flip (to name a few). While some variables remained rather stable when testing a wide variety of objects, other variables were dependent on the size and complexity of a bone or fossil. Some of these variables include the number of pictures needed for a good model, angle of rotation, and camera distance from the specimen. Smaller and simpler bones generally needed more photos taken at smaller angles of rotation. This would allow the Reality Capture software to generate more points on the point cloud. In some cases, model generation was rather difficult with Reality Capture not being able to digitize very small or thin bones such as the last of the tail vertebrae and ribs belonging to smaller animals. This was probably due to the inability of being able to properly position these bones as well as the difficulty of being able to fit these bones into most of the camera frame.

The methods produced in this research will hopefully allow model generation to be more feasible for future research students who will need it for studies such as geometric morphometrics. It can also be noted that the models produced can be used for creating 3D printed versions of a digitized bone which could be helpful with very fragile bones and fossils.

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