Bridging the Past and Present: Reimagining the Dinosaur Physiology from Fossils using 3D [VAE or SD t.b.a.]

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1 INTRODUCTION

Insert exact algorithm

In this work, I present a framework to reconstruct dinosaurs based on their skeleton. To do this, a model is trained to generate a 3D model of an animal based on the animal's skeleton. This model is then applied to the reconstruction of fossilized vertebrate skeletons. The resulting 3D models generated by the model will help us better understand dinosaur physiology.

Before, the reconstruction from fossils was done by hand, closely following the hints found in fossilized bones and impressions, and by comparison with animals living relatives of dinosaurs, like birds and crocodiles. Below, a short motivation is given, followed by an extended problem and a short section describing the structure of this proposal.

1.1 Motivation

Approximately 66 Million years ago [8] an asteroid struck the earth near what is now Mexico [6]. The impact of the asteroid and the following environmental catastrophe probably lead to the mass extinction at the Cretaceous/Tertiary boundary [1].[1] All non-avian dinosaur species went extinct, but it created the evolutionary niche that allowed mammals and birds to strive [4].

Today, some of these mammals try to reconstruct the appearance and lifestyle of dinosaurs from the geological record. Some aspects of dinosaurs' physiology are impossible to understand based on stones alone. Nonetheless, in recent years many features previously believed to be impossible to know, like skin color or sex, were figured out for some species or specimens [9, 10].

Figure 1 shows how C. M. Kosemen imagines our reconstruction of a hippo would have looked like if we only knew their skeleton Conway et al. [5]. This illustrates the main problem in reconstructing animals from their skeletons: Almost all soft matter is lost in almost all cases.

In recent years, some spectacular fossil finds and the application of new techniques give us a much more realistic image of extinct animals [3]. For example, using accurate computer tomography (CT) on impressions of feathers, it was in some cases possible to find out the coloring of the feathers [10].

Still, the skeleton holds many clues about an animal's physiology. Comparing the skeletons and physiology of different animals gives insights into their relationship. This can be utilized to find out more about extinct species, for example by finding extended phylogenetic brackets [3]. It is possible that a lot of cues and unknown relationships are still hidden in the phylogenetic tree that could be exploited for more accurate representations of dinosaurs.

1.2 Problem Statement

This kind of large-scale pattern recognition is a strength of deep learning. Following the explanations above, I propose the application of

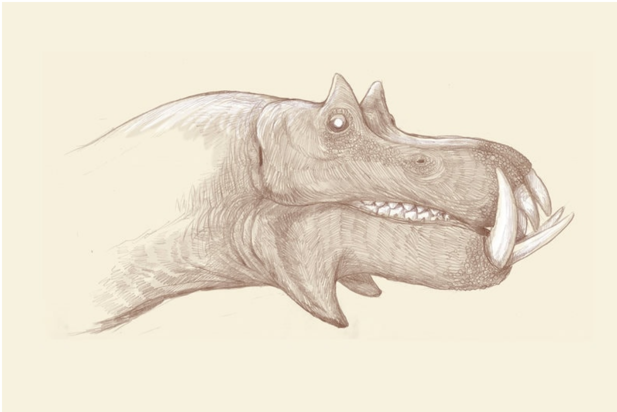

Figure 1: A speculative artistic reconstruction by C. M. Kosemen, imagining how the head of a hippo would appear if reconstructed solely from its skull [5]. He is guided by the techniques used to reconstruct dinosaurs from the skeleton. There is also a meme on this in Appendix A

Some 3D generation algorithms yet to be determined. Probably VAE or SD.

to generate better representations of dinosaur physiology. A model is trained on 3D scans of real living animals. Based on the skeletons of the animals, the model learns to predict the outer body shape of the animal. Training it to predict other characteristics like skin color is probably not feasible. Additional information concerning the animal may be provided, for example, the climate of its habitat[2].

The models performance is then evaluated in two steps: First using 3D scans of animals not used in the training set. Second, by applying the model to accurate 3D models of extinct vertebrates' skeletons. The performance of these skeletons can then be evaluated using fossilized impressions. This step cannot be automated, as impressions do not resemble 3D models.

1.3 Organization of the Work

In the next section, important works regarding the reconstruction of fossilized vertebrates and the deep learning algorithms used are discussed. Section 3 describes how the dataset is created from animal scans and completed skeletons of fossils. The model trained on this data is described in Section 4. The last section takes a look at the expected challenges and limitations of this study.

[1] Over 100 other theories were proposed for the reason of the mass extinction at the Cretaceous/Tertiary boundary; most of them without any scientific evidence [2].

[2] Climate has a huge impact on an animal's appearance. Animals living in hot habitats like deserts have often larger extremities while animals living in cold habitats have thicker layers of fat.

2 RELATED WORK

2.1 Vertebrate Paleontology

2.2 Deep Learning Methods of Generating 3D Structures

3 DATASET

3.1 3D Models of Living Animals

3.2 3D Scans and Models of Extinct Animals'/Dinosaurs' Skeletons

3.3 Fossilized Impressions of Animals/Dinosaurs for Evaluation

4 METHODS

5 CHALLENGES AND LIMITATION

This section deviates from the structure predetermined in the lecture. Working with fossils comes with a lot of uncertainties that must be called out.

- Near impossible to find the sex of a dinosaur from the skeleton alone. The biological sex strongly influences the appearance of many animals, especially birds.
- Small bones are almost never preserved. E.g., only one columella was found (in mammals, this bone is called the stapes; it's the smallest bone in the human body). [7]
- Almost none skeleton is complete. Missing bones are often copied from other skeletons of the same species or mirrored from the other body half. Fossils are also often deformed by the pressure of the aggregate.
- Incredible size differences. Frogs of the species Paedophryne amauensis are less than 8mm long. Argentinosaurus reached more than 30m in length. The size of an animal is incredibly important for the appearance of an animal: Large animals often have no fur (like elephants) to improve heat dissipation. [7]
- Unique features of dinosaurs. It is assumed that large sauropods breathed into their bones to dissipate more heat. [7]