Dinosaur Choir: Adult Corythosaurus

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Lambeosaurine hadrosaurs are duck-billed dinosaurs known for their large head crests encasing elaborate nasal passages. Researchers hypothesize these large crests were resonators for their vocalizations. *Dinosaur Choir* brings these calls to life as singing dinosaur musical instruments. Musicians and participants give voice to these dinosaur instruments by blowing into a mouthpiece, exciting a syrinx (bird vocal box) computational model and resonating the sound through the dinosaur's nasal cavities and skull. The video documentation can be viewed anonymously here: https://vimeo.com/1026355696?share=copy.

Additional Key Words and Phrases: dinosaur, hadrosaur, installation, NIME, physically-based modeling synthesis

1 Program Notes

Fig. 1. *Dinosaur Choir* in action..

Dinosaur Choir: Adult Corythosaurus recreates the sounds of dinosaurs as singing dinosaur skull musical instruments. Gallery visitors and musicians give voice to this musically interactive installation by blowing into a microphone, exciting a computational vocal model and resonating the sound through a 3D printed replica of the dinosaur's nasal cavities and skull. They also change the pitch and timbre of the vocalization by changing the shape of their mouths as they blow into the instrument, not unlike a trumpet player. We realize the skull of an adult Corythosaurus, a lambeosaurine hadrosaur with a large hollow crest housing twisting nasal passages that scientists hypothesize were used for sound resonation. The skull and internal, hollow nasal passages are created via CT scans (Computational Tomography) of an adult Corythosaurus skull

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fossil (ROM 1933) and 3D fabrication technology. Via the intimate action of giving breath to this extinct creature, we hope to stimulate excitement and educate the public about dinosaurs, paleontology, and raise awareness of global ecologies.

While science is one way of knowing the world, Dinosaur Choir explores how a musical instrument can also produce knowledge. One way a musical instrument produces knowledge is empathy. The dinosaur skull instrument becomes a part of them in a similar way that the piano becomes inseparable from the embodied self of the pianist in the moments of playing. They know the dinosaur sound not only via incorporeal simulation and data, but also via the body's effort, tension, and delicate maneuverings to produce the dinosaur's varied utterances. Together, they create the sound world of the piece, creating a symbiotic imagination of human and an animal so long extinct all we have left are mummies and bones.

2 Project Description

Dinosaur Choir: Adult Corythosaurus is part of a larger project realizing dinosaur vocalization. Previous work realized a subadult (adolescent) Corythosaurus with a smaller, immature crest [1]. Additionally, our previous dinosaur skulls employed a physically constructed larynx, but this musical instrument uses a computational vocal model and a novel mouth-tracking interface allowing gallery visitors a new way of driving the dinosaur sound. Future work looks forward to also realizing a Corythosaurus juvenile skull, as crest changes with age, as well as realizing different dinosaur species beyond the Corythosaurus. Recent paleontological evidence that suggests that dinosaurs may have had a syrinx (bird vocal box) rather than a larynx, like mammals and their crocodilian relatives [9]. While dinosaur vocal organs are still an actively debated question in paleontology [3], we were inspired by the more recent research to base dinosaur vocal anatomy on the bird syrinx.

The bioacoustic dinosaur syrinx (bird vocal box) model is written using Web Audio API[1] and written as a ToneJS [2] plug-in/audio worklet. ToneJS is also used for sound input and dynamics post-processing. We developed two dinosaur syrinx models. The first model modifies the Fletcher (1988) model [6] [7] and Smyth & Smith (2002) [8] [4] implementation, which is based on a raven vocal anatomy and the second model modifies the Elemans, Zacarelli, et. al. (2006-2009) model [5] [10], which is based on dove vocal anatomy. Some of the main differences between the models are due to the differing bird anatomies, as ravens are songbirds and thus have specialized vocal boxes with two vocal membranes in each bronchus. Doves only have one vocal membrane in the tracheal tube, generally thought to be the ancestral condition [3] [2], so it is possible but far from certain that the dove model may be more accurate for dinosaurian sound. Parameters such as trachea length and syringeal membrane width are based on Corythosaurus skeleton and skull measurements. Other parameters (vocal cord tension ranges, input air pressure ranges) are modified in order to produce sound given the previous parameters. Placement of the syringeal membrane was estimated using measurements, ratios, and diagrams of bird anatomy. All estimated parameters of unpreserved soft tissue data are based on informed speculation and thus, are both "best guesses" and creative interpretations of missing biological data. Participants can change fixed parameters, such as vocal anatomy (e.g., tracheal length) and which model is used to generate sound via QR code and their mobile device, allowing them to speculate as well.

A microphone [3] is used to capture breath input, and Google Mediapipe face landmark detection model[4] is employed for the mouth-tracking. Google Mediapipe is implemented in client-side JavaScript and video used for mouth-tracking is not stored, recorded, or sent to an external server. The code runs the browser via Javascript and is currently running on an iPad Air [5]. Previously, the code ran on a Raspberry Pi 5 [6] and DigiAMP+[7]. However, we found that the previous platform (Raspberry Pi) introduced latency that was solved by moving to a more powerful computer, and further, we were able to use the built-in camera for the mouth-tracking and monitor for visual display with the iPad, simplifying the solution. As our software is machine-independent via the browser, we are able to switch from Raspberry Pi to the iPad without code changes.

In order to drive the model in real-time, microphone audio is translated into dinosaur air sac pressure and mouth shape, determined from optical face-tracking is translated into vocal tension. The wider the mouth horizontally, the greater the tension, and generally, the higher the pitch of the sound. The overall area of the mouth in two dimensions also modulates vocal tension value in finer granularity, with more open and wider mouth shapes creating more vocal tension and more closed mouth shapes less. During experimentation with the model and musical instrument, it was found that the area of

[1] https://developer.mozilla.org/en-US/docs/Web/API/Web_Audio_API
[2] https://tonejs.github.io
[3] https://www.sennheiser.com/en-us/catalog/products/microphones/e-614/e-614-009895
[4] https://developers.google.com/mediapipe
[5] https://www.apple.com/ipad-air/
[6] https://www.raspberrypi.com/products/raspberry-pi-5
[7] https://www.raspberrypi.com/products/digiamp-plus

the open mouth curve had a more interesting and intuitive response than using the horizontal value of mouth openness alone or including a separate vertical measure.

3 Technical Notes

Dinosaur Choir: Adult Corythosaurus requires at least 1m X 1m of space in a gallery, hall, or indoor plaza to be displayed. The work requires proximity to an electrical outlet or another source of external power. WiFi access is required.

3.1 Equipment Artists Provide:

- Hadrosaur skull musical instrument (includes Raspberry Pi, speaker, amp, microphone, webcam)

3.2 Equipment Required from Venue:

- Plinth/Table: 60cm x 120cm minimum surface area required and we will will assume that everything will be placed on an average height table (71-76cm)
- Access to electrical outlets/power
- Access to WiFi required.

3.3 Example floor plan:

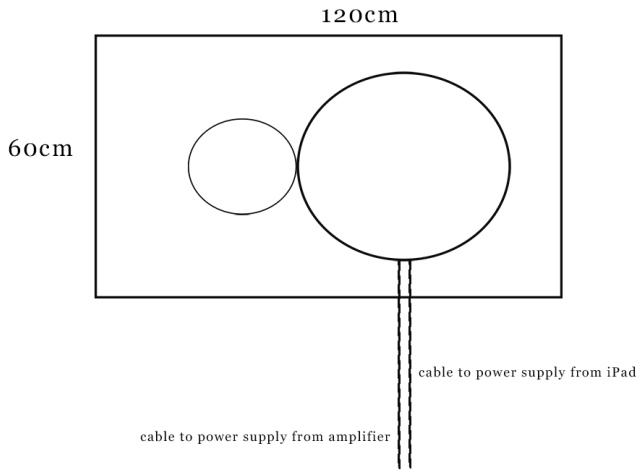

Fig. 2. Floor plan of installation. Instrument contains a speaker, and so simply needs to be placed in a location with access to power.

4 Media Links

Video Documentation:

- Video: https://vimeo.com/1026355696?share=copy

5 Ethical Standards

Dinosaur Choir has been made accessible to the public as an interactive installation displayed at a public museum and a talk open to the public at several locations and used in several public performances. Our code is also open-source and the interactive dinosaur sound can be experienced remotely (without the physical skull) via an interactive website. We also have plans to release open-source 3D models upon approval from our paleontological collaborators upon publication of their own research.

No empirical user studies have been performed with the instrument, so issues of inclusion in that context are not relevant to this work.

Dinosaur Choir is fabricated using PLA plastic, but unlike previous versions does not require replaceable parts and thus is more sustainable.

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