

Development of a Whole-body Skeletal Model of a Rat Based on Anatomical Landmarks for Detailed Motion Analysis

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Abstract—We developed a fine-grained and whole-body rat skeletal model for a preliminary motion analysis to investigate its feasibilities and current limitations. To obtain geometrical data, we used high-resolution X-ray computed tomography data. We processed the volume data to prepare skeletal segments to develop the whole-body model based on rat anatomical landmarks. The skeletal model has 110 segments and 168 degrees of freedom. We measured rat motion data using a conventional motion capture system and conducted a preliminary inverse kinematics analysis. The results suggest that our method is feasible to analyze neuromotor functions of model animals. On the other hand, we still need improvements in the method used for motion data acquisition owing to the soft tissue artifacts and effect by scaling.

I. INTRODUCTION

Neuromotor functions are important phenotypes to elucidate mechanisms of neurological diseases. Owing to the extreme complexities of their phenotypes, we often need invasive measurements to obtain significant data from non-human model organisms such as rodents. Regarding biomedical applications, however, we sometimes face difficulties to extrapolate phenotypes from the model organisms to humans. To bridge these gaps, we need to elaborate on macroscopic phenomena rather than microscopic phenomena. Our approach was to apply a biomechanics framework to solve this problem [1].

Rats are widely used as a non-human model organism in neuroscience for invasive measurement. However, existing rat biomechanics models are still crude and need to be refined. Therefore, we developed fine-grained whole-body skeletal model of a rat for detailed motion analysis. We measured the gait pattern of the rat with a conventional motion capture system and performed an inverse kinematics (IK) analysis.

II. METHODS

A. Development of the skeletal

After sacrificing three rats with deep anesthesia, we scanned them in a frozen state using dimensional X-ray computed tomography (CT) with maximum resolution (59 μ m). The obtained volume data were segmented into 110 bones at the articular parts. We defined the joint coordinate system according to the anatomical landmarks used in previous works, namely Johnson et al. (2008).

B. Motion analysis

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We measured gait patterns of the rat on a sloped beam using a motion capture system (Motion Analysis Corporation, Santa Rosa, CA). Motion data were acquired using reconstructed trajectories of 19 experimental markers on the rat skins. After scaling the skeletal model to the rat, we conducted IK with OpenSim [2]. The experimental protocols were approved by the institutional committee for animal experiments at AIST.

III. RESULTS

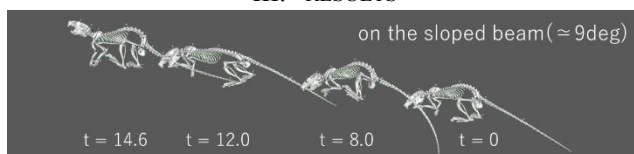


Figure 1. Visualization of a gait pattern with the developed skeletal model

We developed an IK-ready skeletal model based on the high-resolution X-ray CT scanning data (Fig. 1). Fig. 2 shows the average gait cycles with normalized time and rotation angles during flexion/extension with gait phases (0.08 m/s). The maximum differences between the experimental and the model markers were 12 mm, 11 mm, 8 mm, and 7.5 mm at the shoulder, elbow, waist, and knee, respectively.

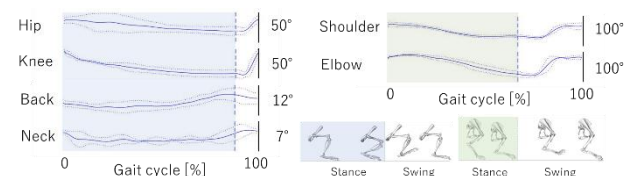


Figure 2. Mean angles of each joint of the rat during walking gaits.

IV. DISCUSSION & CONCLUSION

We developed a whole-body skeletal model of rats and showed that a full-body IK analysis is feasible using our rat skeletal model with only 19 retroreflective markers. On the other hand, we considered deviations of the model markers from the corresponding experimental markers were mainly caused by the soft tissue artifacts and effect by scaling. In our future work, we will improve the data acquisition method to overcome the current limitations and attempt to conduct various analyses with an enhanced musculoskeletal model.

REFERENCES

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