# NEW INSIGHTS FOR THE DESIGN OF BIONIC ROBOTS

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## Abstract

**Introduction:** Felines have significant advantages in terms of sports energy efficiency and sports flexibility compared with other animals, especially in terms of jumping and landing. The biomechanical characteristics of a feline (cat) landing from different heights can provide new insights into bionic robot design based on research results and the needs of bionic engineering. The purpose of this work was to investigate the adaptive motion adjustment strategy of the cat landing using a machine learning algorithm and finite element analysis.

**Methods:** This study combined the inverse kinetics model and the deep learning method to achieve the purpose of exploring the biomechanical characteristics of the whole landing phase of the cat, as well as the coordination strategy of each joint of the cat's forelimb when landing at different heights (Fig 1). Therefore, in order to more comprehensively explore the biomechanical characteristics of cat landing, the current study was mainly carried out from two aspects: 1) PCA and FEA (Fig 2); 2) inverse kinetics and deep learning method (DNN and LRP). Firstly, the GRF and joint kinematics (sagittal joint angle of wrist elbow shoulder) were collected when the cat landed from 4 different heights (60cm, 80cm, 100cm, 120cm). The landing phase was determined as the initial contact point to maximum elbow flexion. Then, the next steps are mainly divided into two steps.

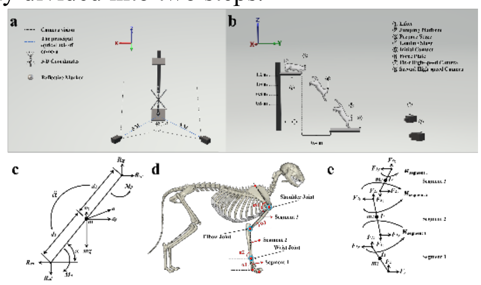

*Figure 1: (A) Illustration of the position of two high-speed cameras and 3-D coordinates. (B) Illustration of cat landing procedure from the ready position to initial forelimbs contact the ground. (C) The complete free-body diagram of a single forelimb segment (D) Illustration of the position of red marker points on forelimbs of cats (E) Freebody diagrams of the three rigid links.*

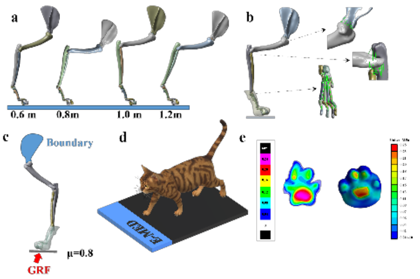

*Figure 2. (A) Finite element 3D model of right forelimb at four landing heights. (B) Illustration of ligament and soft tissue of model. (C) Illustration of loading and boundary conditions. (D) Experimental verification of plantar pressure of cat right forelimbs. (E) Experimental verification results and finite element simulation results.*

**Results and Conclusion:** In the design of a bionic robot, there are considerations in the design of the mechanical legs: 1) The coordination mechanism of each joint should be adjusted intelligently according to the force at the bottom of each mechanical leg. Specifically, with the increase in force at the bottom of the mechanical leg, the main joint bearing the impact load gradually shifts from the distal joint to the proximal joint (Fig 3); 2) Strengthening the hardness of the materials located around the center of each joint of the bionic mechanical leg to increase service life (Fig 4); 3) Lower the center of gravity of the robot and keep the robot posture forward as far as possible to reduce machine wear and improve robot operational accuracy.

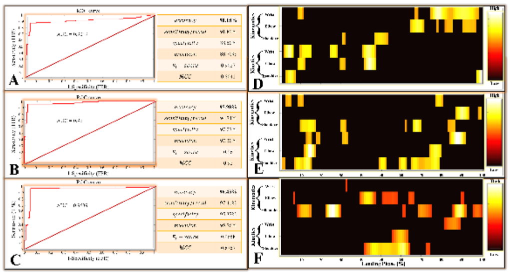

*Figure 3. The classifier performance results of the DNN models.*

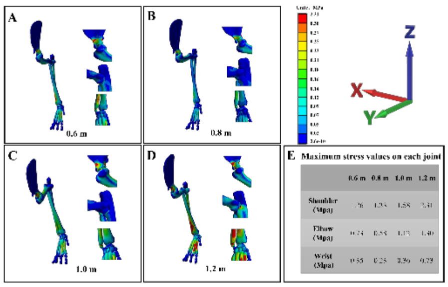

*Figure 4. (A) (B) (C) (D) are the stress distribution details of the wrist joint, elbow joint and shoulder joint of the cat's right forelimb landing from four heights of 0.6m, 0.8m, 1.0m and 1.2m respectively. (E) The maximum stress value of each joint at each landing height.*