Modeling, Design and Simulation of Falling and Landing Process in a Robotic Cat

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Abstract:

Motion dynamics of cat species has always been attractive to be studied. Flexibility in motion due to specific skeleton and complex muscle-skeleton mechanism, control concepts, special way of running, high speed of changing direction while moving, ability of twisting the body during free fall, and landing on four limbs were widely investigated in literature and the results have been used in different branches such as control, robotics and aerospace.

In this project, kinematic and dynamic equations are derived for a simple two-link robot, a three-link robot with tail, and a more complete eight-link model with the addition of legs which is designed utilizing the animal's anatomy. Dynamic equations are derived based on the iterative TNT method which eliminates the highest order derivative in each step and results in a simplified matrix form, ideal for numerical calculations. A path planning algorithm, using semi-flat kinematic equations, similar to input-output linearization method in nonlinear control, is used in the absence of constraints to calculate the preferable amounts of inputs for any desired output values. To satisfy geometric, kinematic and dynamic constraints, a single shooting optimization method is applied to estimate the desired input values. The maneuver is also analyzed in presence of legs' motion and it is shown that their movements can only prepare the body configuration for impact without considerable improvement in the free fall features. To satisfy the control purpose, an extended Kalman filter is used to reject the noise generated by gyroscopes which measure the spatial rotation angles and an off-line neural network based identification is used to compensate the uncertainties of the model. The free fall motion is improved by optimizing the dimensions and inertia properties of the links.

Furthermore, a three-phase landing is studied using force-control algorithms. The landing phases are: pre-landing in which the robot adopts the optimal configurations to absorb the in-joint impulses, single-contact in which the robot is settled on one pair of its limbs, and double-contact in which the second pair impacts the ground. In each step, desired input values are calculated so as to guarantee the stability of the body based on ZMP index, and reduce the impact force in contacting points using input-output linearization and single shooting optimization methods. Finally, the results are compared with a computer simulation in ADAMS software for validation.