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Approximate Spring Balancing for the Arm of a Humanoid Robot to Reduce Actuator Torque

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Abstract : The potential benefit of gravity compensation of linkages in mechanisms using springs to reduce actuator requirements is well recognized, but practical applications have been elusive. Although existing methods provide exact spring balance, they require additional masses or auxiliary links, or all the springs used originate from the ground, which makes the resulting device bulky and space-inefficient. This paper uses a method of static balancing of mechanisms with conservative loads such as gravity and spring loads using non-zero-free-length springs with child–parent connections and no auxiliary links. Application of this method to the developed arm of a humanoid robot is presented here. Spring balancing is particularly important in this case because the serial chain of linkages has to work against gravity.This work involves approximate spring balancing of the open-loop chain of linkages using minimization of potential energy variance. It uses the approach of flattening the potential energy distribution over the workspace and fuses it with numerical optimization. The results show the considerable reduction in actuator torque requirement with practical spring design and arrangement. Reduced actuator torque facilitates the use of lower end actuators which are generally smaller in weight and volume thereby lowering the space requirements and the total weight of the arm. This is particularly important for humanoid robots where the parent actuator has to handle the weight of the subsequent actuators as well. Actuators with lower actuation requirements are more energy efficient, thereby reduce the energy consumption of the mechanism. Lower end actuators are lower in cost and facilitate the development of low-cost devices. Although the method provides only an approximate balancing, it is versatile, flexible in choosing appropriate control variables that are relevant to the design problem and easy to implement. The true potential of this technique lies in the fact that it uses a very simple optimization to find the spring constant, free-length of the spring and the optimal attachment points subject to the optimization constraints. Also, it uses physically realizable non-zero-free-length springs directly, thereby reducing the complexity involved in simulating zero-free-length springs from non-zero-free-length springs. This method allows springs to be attached to the preceding parent link, which makes the implementation of spring balancing practical. Because auxiliary linkages can be avoided, the resultant arm of the humanoid robot is compact. The cost benefits and reduced complexity can be significant advantages in the development of this arm of the humanoid robot.

Keywords : actuator torque, child-parent connections, spring balancing, the arm of a humanoid robot
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