Mechanical Engineering Doctoral Defense

Optimal Design Methods for Increasing Power Performance of Multiactuator Robotic Limbs

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abstract

In order for assistive mobile robots to operate in the same environment as humans, they must be able to navigate the same obstacles as humans do. Many elements are required to do this: a powerful controller which can understand the obstacle, and power-dense actuators which will be able to achieve the necessary limb accelerations and output energies. Rapid growth in information technology has made complex controllers, and the devices which run them considerably light and cheap. The energy density of batteries, motors, and engines has not grown nearly as fast. This is problematic because biological systems are more agile, and more efficient than robotic systems. This dissertation introduces design methods which may be used optimize a multiactuator robotic limb's natural dynamics in an effort to reduce energy waste. These energy savings decrease the robot's cost of transport, and the weight of the required fuel storage system. To achieve this, an optimal design method, which allows the specialization of robot geometry, is introduced. In addition to optimal geometry design, a gearing optimization is presented which selects a gear ratio which minimizes the electrical power at the motor while considering the constraints of the motor. Furthermore, an efficient algorithm for the optimization of parallel stiffness elements in the robot is introduced. In addition to the optimal design tools introduced, the KiTy SP robotic limb structure is also presented. Which is a novel hybrid parallel-serial actuation method. This novel leg structure has many desirable attributes such as: 3 dimensional end-effector positioning, low mobile mass, compact form-factor, and a large workspace. We also show that the KiTy SP structure outperforms the classical, biologically-inspired serial limb structure.

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