An Energy Saving Control Method of Robotic Systems Utilizing Adaptive Stiffness Adjustment

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Recently, the importance of energy saving is increasing dramatically due to environmental problems. For mechanical systems, energy saving is one of the most fundamental requirements in general. Especially, for mobile robots and walking robots, energy saving is essential because they must install batteries in themselves. From a biological viewpoint, the energy saving mechanism is interesting because it is expected that animals and human beings seem to save energy as much as possible.

If the motion of mechanical systems is periodic, it is well known that resonance is effective in order to reduce energy for the actuators of the mechanical system. Unfortunately, however, the concept of resonance can be applied only for a case that the system is linear and one degree-of-freedom, and motions are sinusoidal.

Therefore, the concept of resonance can not be directly utilized for more complex systems such as multi-joint robots or non-sinusoidal motions.

To overcome this difficulty, this dissertation proposes a new energy saving control method of some robotic systems, in which adaptive stiffness adjustment of mechanical elastic elements is utilized. The proposed control method generates periodical motions without using torque of actuators as much as possible utilizing the stiffness adjustment. The proposed control method can be applied for the following four situations.

The first situation is that the controlled objects are multi-joint robots. In this case, dynamics of the controlled objects is nonlinear and degree-of-freedom is multiple. The second one is that the controlled objects have linear dynamics, but the desired periodical motions include multi frequency component. The third one is that the controlled objects are power assist systems that amplify torque of a human operator. In this case, an actuator and an adjustable stiffness device are attached directly to the operator. The fourth one is that the controlled objects are also power assist systems, but an actuator is attached through an elastic element to the operator.

For all situations, stability of the motion and convergence of the stiffness to optimal one are mathematically investigated using scalar functions such as Lyapunov functions. Effectiveness of the proposed control method is demonstrated through simulation and experimental results.