HIGH PERFORMANCE DIFFERENTIAL ACTUATOR FOR ROBOTIC INTERACTION TASKS

FIELD

[0001] The present invention relates to differential actuators. More specifically, but not exclusively, the present invention is concerned with a high performance differential actuator for robotic interaction tasks.

BACKGROUND

[0002] It is well known to those of ordinary skill in the art that an actuator is a mechanism that transforms a particular form of energy, for example electrical, pneumatic or hydraulic energy into mechanical power to induce, in particular but not exclusively, motion. The motion produced by an actuator can be a rotational motion, a linear motion, a combination of rotational and linear motions, or any other type of motion.

[0003] An actuator is described as "high performance" when the actuator has (a) the capability to produce a high output mechanical power in a compact volume, and/or (b) a high efficiency of energy conversion, and/or (c) dedicated sensors to measure its internal kinetic states (forces and/or torques) and its internal kinematic states (positions and/or speeds and/or accelerations).

[0004] Also, a robot with n degree(s) of freedom is connected to a load via n power exchange, interaction port(s), i.e. one per degree of freedom. The state of each interaction port is defined via two variables: a generalized force/torque and a generalized speed. Independent control of these two interaction state variables issued from a same interaction port is not possible. For that reason, two "ideal" actuators are defined for each interaction port, one for each of the two interaction state variables (generalized force/torque and generalized speed), as a model for this concept.

[0005] A so called "ideal actuator" would control perfectly (a) the force/torque profile or (b) the speed profile transmitted to the load. There would be no limitation of frequency and/or amplitude for the desired (a) force/torque or (b) speed profile that can be controlled by this "ideal actuator". Any (a) motion perturbation or (b) force perturbation of the load, at any frequency and amplitude, does not affect the ideal performance of the "ideal actuator". Such an "ideal actuator" would constitute an ideal source of (a) force/torque or (b) speed.

[0006] Real actuators designed to have a performance as close as possible to that of ideal sources of speed are generally implemented using very high mechanical impedance components in series with a transducer. Such a real actuator may include, for example, a hydraulic transducer and a very high ratio mechanical transmission using gears.

[0007] A hydraulic transducer has an intrinsic high impedance property. Accordingly, a hydraulic transducer is well suited to build speed sources having performances close to those of ideal sources of speed.

[0008] A very high ratio mechanical transmission using gears has an intrinsic high impedance property because of friction and inertia amplification. Thus, a high ratio gearbox placed between a transducer and a load will help to reject perturbation forces/torques coming from the load. Consequently, a high ratio gearbox is well suited to build speed sources having performances close to those of ideal sources of speed.

[0009] Real actuators designed to have a performance as close as possible to that of ideal sources of force/torque are generally implemented using very low mechanical impedance components in series with a transducer. Such real actuators may include, for example, direct drive actuators and force/torque controlled actuators.

[0010] A direct drive actuator may comprise an electromechanical transducer that is directly linked to a load, for example a load shaft without gearbox. In general, such an electromechanical transducer has a known relationship between the winding current and the output force/torque. Fast force/torque control can be performed with a feed forward control scheme using an analog current controller. The collocation of a current sensor with the electromechanical transducer allows very high bandwidth operation.

[0011] A force/torque controlled actuator may be an actuator including a high impedance force/torque sensor in series with a real source of speed with high mechanical impedance. The force/torque is controlled by simple feedback control. The bandwidth of such a system is often limited by the non-collocation of the force/torque sensor and the transducer.

[0012] High performance variable impedance actuators for robotic interaction tasks have been developed for applications where the power exchange with the robot's environment is not negligible.

[0013] A large class of robotic applications requires low power exchange during interaction between the robot and its environment. For these simple tasks such as pick and place or slow assembly of simple parts, a precise interaction model between a robot and its environment is easily available. Thus, from a control point of view, feedback based control of movement or force is generally sufficient for the robot to perform these tasks. Both motion and force controllers attempt to reach the same objectives, though each focuses on only one port variable, i.e., pure force control or pure motion control. To perform these tasks, robot designers implement actuators of which the performance is close to the performance of "ideal actuators". However, for applications where the power exchange with the robot's environment is not negligible and involving complex robotic tasks such as manipulation, locomotion, haptics, etc., the lack of knowledge of precise interaction models, the difficulty to precisely measure a robot port's associated physical quantities (force/torque, speed, etc.) in real time and the non-collocation of sensors and transducers have negative effects on the performance and stability of robots when using simple motion and/or force/torque controllers.

[0014] To cope with these issues, an approach named <<interaction control>> that refers to regulation of the robot's dynamic behavior at the ports of interaction with the environment has been proposed. Generally stated, in this particular case, "interaction control" involves specifying a dynamic relationship between speed and force/torque at the port, and implementing a control law that attempts to minimize deviation from this relationship [1].

[0015] Implementation of machines capable to precisely control interaction with the environment begins with the use