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Adaptive robust neural control of a two-manipulator system holding a rigid object with inaccurate base frame parameters

Key words: Cooperative manipulators; Neural networks; Inaccurate translational base frame; Adaptive control; Robust control

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Motivations

The base frame parameters, which determine the relative translation and rotation among base frames of the coordinated manipulators, present a fundamental kinematic problem for coordinated cooperative manipulator systems:

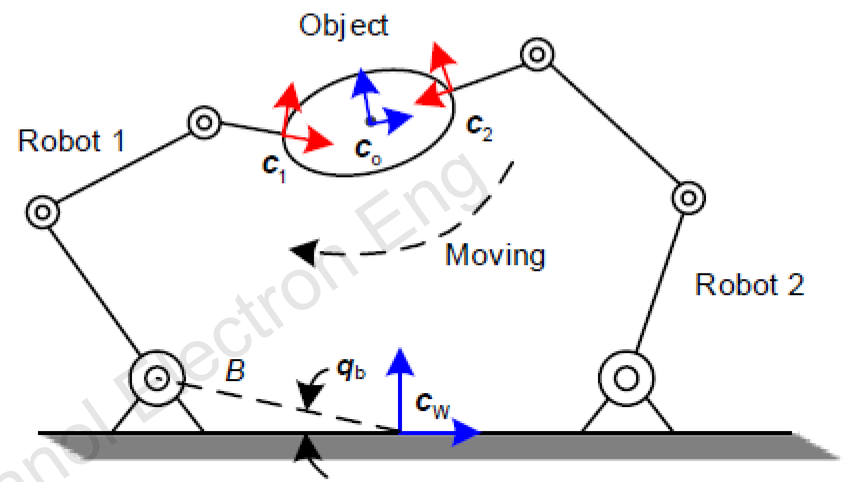

Fig. 1 **Two cooperative manipulators holding a rigid object**

(1) **Inaccurate base frame parameters** (the base frame affects the closed kinematic chain directly, but most control algorithms have seldom considered inaccurate base frame parameters);

(2) **Internal force** (permanent damage to an object may occur with unmanaged internal force, but most of the existing coordinated control methods ignore internal force or require specific force sensors);

(3) **Uncertain dynamics, joint frictions, and external disturbances** (for most cooperating controllers, dynamic knowledge of manipulators and environment is more or less necessary, which is always practically out of reach).

Main ideas

1. In many modern manufacturing applications, it is necessary to move a large and heavy payload using cooperative manipulators that must share the load and provide stiffness. It is much more complicated to design a controller of cooperative manipulation.

2. Precision end-point or camera-based measurement systems are required to calibrate the relative kinematic parameters of the manipulators.

3. The proposed method permits accurate online calibration of the relative translational base frame parameters of the involved manipulators.

Methods

1. A new set of kinematic parameters is established, and translational base frame parameters are considered a part of the robotic kinematic parameters.

2. A radial basis function neural network is adopted for all kinds of dynamical estimation, including undesired internal force.

3. Besides NN estimation, robustness is achieved with an additional robust control procedure that could cope with dynamic and kinematic estimating errors.

4. Various simulations have been conducted based on the proposed framework.

Major results

1. The proposed method guarantees that the position tracking errors are shown to asymptotically converge to zero.

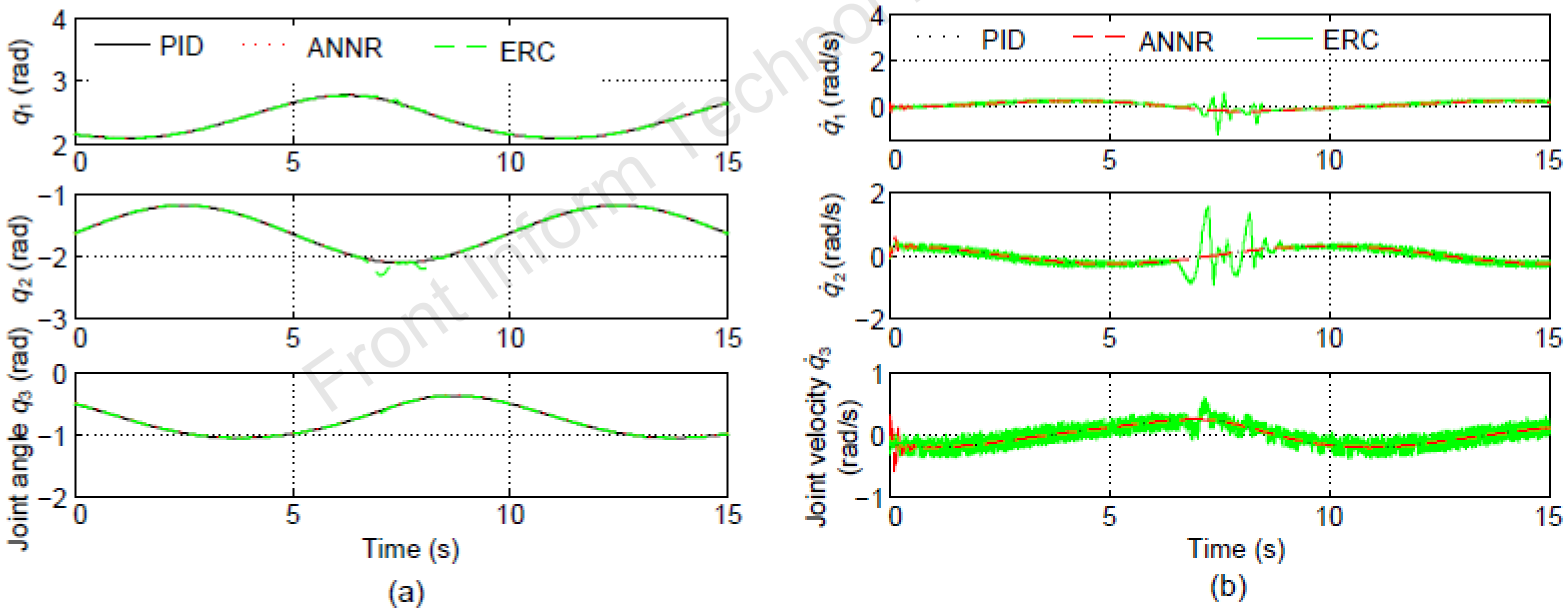

Fig. 3 Joint angle and velocity under a circular trajectory: (a) joint angle; (b) joint velocity

Major results

2. The proposed method permits accurate online calibration of relative translational base frame parameters of the involved manipulators.

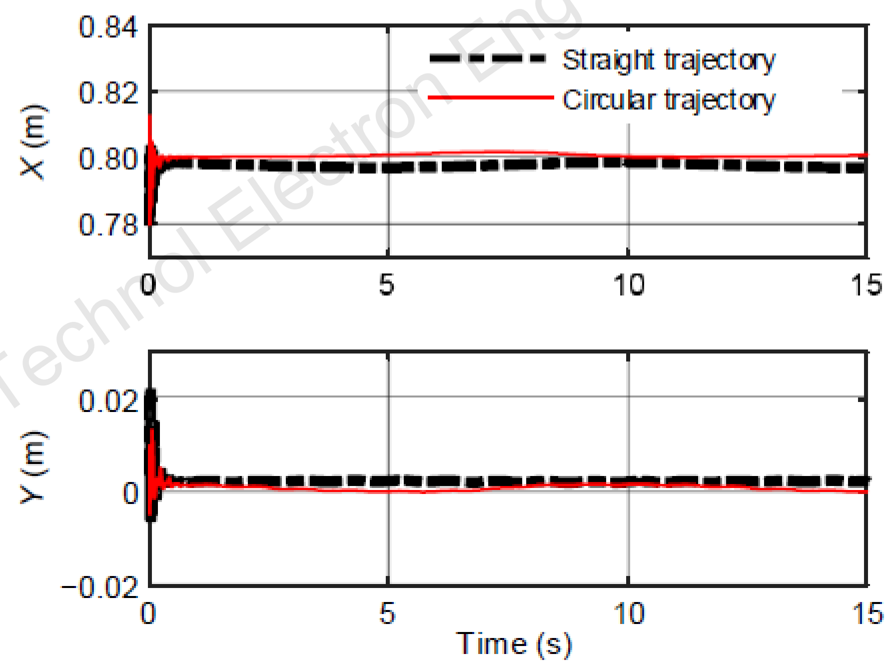

Fig. 6 Estimation of relative translational base frame parameters

Conclusions

1. A novel adaptive and robust neural controller has been constructed to cope with the inaccurate translational base frame parameters, modeling uncertainty, unknown joint frictions, and external disturbances within cooperative manipulation.

2. No prior knowledge of the system dynamics is required. The adopted RBF NN estimation performs well despite uncertain modeling, joint frictions, external disturbances, and more importantly, the internal force.

3. Besides NN estimation, robustness is achieved with an additional robust control procedure that could cope with dynamic and kinematic estimating errors.

4. The proposed approach guarantees that both the global tracking error and the synchronization error converge to 0 asymptotically and simultaneously, and keeps the internal force in an acceptable range steadily.