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Adaptive manipulation and slippage control of an object in a multi-robot cooperative system

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SUMMARY
Considering undesired slippage between manipulated object and finger tips of a multi-robot system, adaptive control synthesis of the object grasping and manipulation is addressed in this paper. Although many studies can be found in the literature dealing with grasp analysis and grasp synthesis, most assume no slippage between the finger tips and the object. Slippage can occur for many reasons such as disturbances, uncertainties in parameters, and dynamics of the system. In this paper, system dynamics is analyzed using a new presentation of friction and slippage dynamics. Then an adaptive control law is proposed for trajectory tracking and slippage control of the object as well as compensation for parameter uncertainties of the system, such as mass properties and coefficients of friction. Stability of the proposed adaptive controller is studied analytically and the performance of the system is studied numerically.

KEYWORDS: Adaptive control; Slippage control; Cooperative robots; Frictional contacts.

Nomenclature

$\mathbf{B}$	Coefficient matrix of the input torques
$\tilde{\mathbf{B}}$	Coefficient matrix of the input torques in reduced order form
${}_{\mathrm{I}}\mathbf{C}_{\mathrm{o}}$	Rotation matrix of the object frame with respect to the inertial frame
${}_{\mathrm{I}}\mathbf{C}_{\mathrm{c_i}}$	Rotation matrix of the ith contact frame with respect to the inertial frame
$\mathbf{F}$	Vector consisting of friction and normal forces exerted by end-effector on the object
$\mathbf{h}$	Coriolis-centrifugal-gravity matrix
$\tilde{\mathbf{h}}$	Coriolis-centrifugal-gravity matrix in reduced order form
$\mathbf{I}$	Identity matrix
I_{o}	Object moment of inertia
$\mathbf{J}$	Jacobian matrix
$\mathbf{K}_p$	Constant semi-positive definite matrix
$\mathbf{K}_v$	Constant positive definite matrix
k	Number of joints
l	Length of manipulator's link
L_{o}	Distance between the object center of mass and its edges

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