International Journal of Structural Stability and Dynamics

STABILIZATION OF INTERNAL DYNAMICS OF UNDERACTUATED SYSTEMS BY PERIODIC SERVO CONSTRAINTS

LÁSZLÓ BENCSIK
MTA-BME, Research Group on Dynamics of Machnines and Vehicles
Műegyetem rkp. 5, Budapest, H-1111, Hungary
bencsik@mm.bme.hu

LÁSZLÓ L. KOVÁCS
Centre for Intelligent Machines, Department of Mechanical Engineering, McGill University,
817 Sherbrooke Street West, Montreal, Quebec, H3A 0C3, Canada
laszlo.kovacs@mcgill.ca

AMBRUS ZELEI
MTA-BME, Research Group on Dynamics of Machnines and Vehicles
Műegyetem rkp. 5, Budapest, H-1111, Hungary
zelei@mm.bme.hu

The model based motion control of underactuated, multiple degree-of-freedom, complex multibody systems is in focus. Underactuated mechanical systems possess less number of independent control inputs than degrees-of-freedom. The main difficulty in their control is caused by the dynamics of the uncontrolled part of the system. The complexity of multibody systems makes the dynamical and control formulation difficult.

The direct application of traditional control techniques available in the literature can lead to unstable dynamic behaviour in many cases. In order to avoid instability, these general methods are usually adapted for specific problems in an intuitive way. Here we present a direct, more algorithmic approach, and propose the use of periodic servo-constraints to overcome stability problems and enhance dynamic behaviour. An exact, stability analysis based method is also proposed for tuning the control parameters.

A stability analysis procedure is developed which is directly applicable for investigating the dynamics of mechanical systems described by dependent coordinates and mathematically formulated as a set of algebraic differential equations.

Keywords: underactuated multibody systems; internal dynamics; servo-constraints; direct eigenvalue analysis; stabilization; switched control.

1. Introduction

The task of a robotic manipulator can be specified by the so called *servo-constraints*.[1,2] In case of an *underactuated* robot the motion of the whole system is only *partially* prescribed. Due to this fact, these robots have *internal dynamics* which often affects negatively the controlled motion.

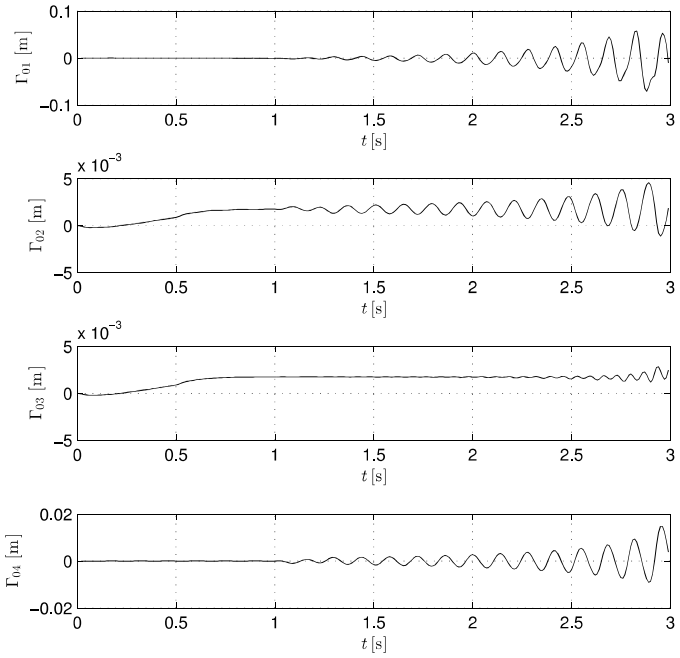

Fig. 5. Servo constraint violation with original servo-constraints

6. Conclusions

The present paper investigates the dynamic behaviour of underactuated systems, when the internal dynamics is stabilized by periodic servo-constraints. Also a direct eigenvalue analysis procedure was proposed for the stability investigation of multibody systems described by a DAE with differentiation index 3.

Based on the stability analysis it can be concluded that the presented control approach can effectively improve the dynamical performance of underactuated systems via the stabilization of the internal dynamics. The presented stability analysis is a practical tool in general choosing an optimal switching pattern for systems with periodic controllers.

A detailed stability analysis was carried out in case of a service robotic example. The results demonstrated the applicability of the proposed method of direct eigenvalue analysis. Numerical simulations confirmed the predicted stability properties and demonstrated that the application of periodic servo-constraints can make the realization of an otherwise unstable computed torque controller possible. In the presented example, not only stability was regained, but also the original task was realized with sufficient accuracy.