Model-based and Model-free Control of a Parallel Manipulator with Flexible Links

Maíra Martins da Silva and Fernanda Thaís Colombo
Department of Mechanical Engineering, São Carlos of Engineering, University of São Paulo, Brazil

Abstract. Parallel manipulators may become more energy efficient by reducing their components' inertia. Nevertheless, this reduction might yield vibrations requiring novel joint and task space control strategies. While the former may involve precise models, the latter can be accomplished by adequate computation vision schemes, which impose critical challenges. This work compares two feedback control approaches composed of two control loops. One of these loops is a position-based visual servo that controls rigid-body motion. We implemented the second loop using: (1) a model-based LQG strategy and (2) a model-free strain-based approach. Compared with the position-based visual servo scheme, both strategies attenuate the vibrations and reduce the overshoot response.

Introduction

Designers can improve the parallel manipulators (PMs)' energy efficiency by reducing their moving components' inertia [1]. However, this reduction might yield undesired vibrations due to the components' flexibility, requiring more complex modeling and control strategies.

The literature on modeling and controlling PMs with rigid links is vast. On the other hand, the literature on modeling and controlling PMs with flexible links is scarce, as stated by [2]. Regarding flexible manipulators, the vast majority of the works investigate flexible multi-link serial manipulators. However, controlling the parallel machines may be complex due to their coupled and non-linear dynamics. Moreover, a direct measurement of the manipulator's end-effector pose (position and orientation) may require vision-based measuring techniques. We attenuate the vibration of a parallel planar manipulator with flexible links depicted in Fig. 1(a). This figure shows a 3PRRR with flexible links, which is a kinematic redundant PM since there are two active joints in each kinematic chain. Nevertheless, the prismatic joints are blocked, yielding the non-redundant 3RRR. In this field, R, S, and P stand for revolute, spherical, and prismatic joints. The underlined letters represent the active joints (Motor 1, Motor 2, and Motor 3), while the others are passive.

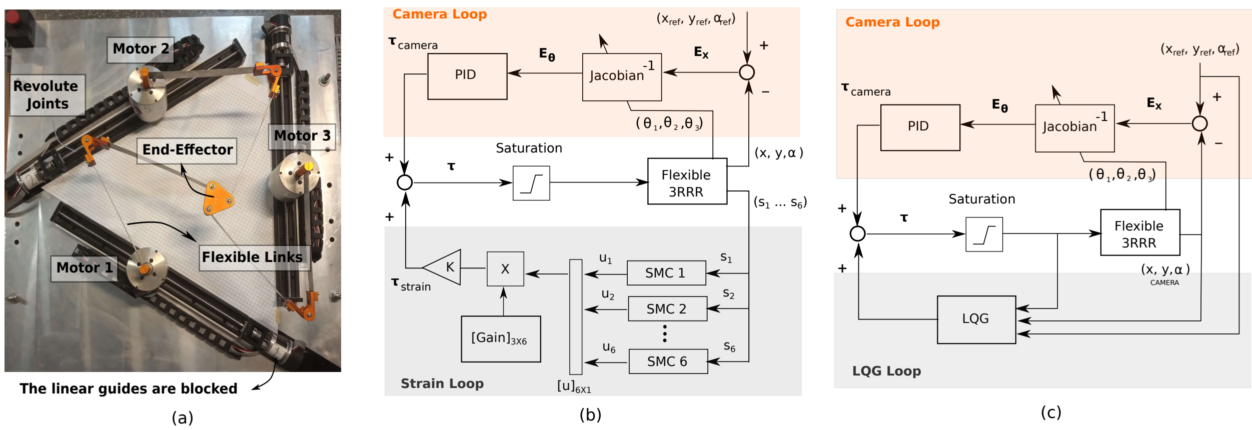

Figure 1: (a) 3RRR with flexible links, (b) Model-free strain-based feedback control strategy, and (c) Model-based LQG control strategy

Results and Discussion

This work compares two feedback control approaches composed of two control loops as illustrated in Fig. 1(b) and (c). One of these loops is a position-based visual servo that controls rigid-body motion (CAMERA Loop). We implemented the second loop using: (1) a model-free strain-based approach (Strain Loop in Fig. 1(b)), and (2) a model-based LQG strategy (LQG Loop in Fig. 1(c)). The model-free strategy requires the use of dedicated instrumentation. In this work, strain gauges measure the deformation of the flexible links. On the other hand, the model-based approach requires a suitable model for deriving the LQG gains. In this work, a reduced model is derived from a multibody finite element model. Compared with the position-based visual servo scheme, both strategies attenuate the vibrations and reduce the overshoot response by 50%.

References

[1] Ruiz A.G. , Santos J.C., Croes J., Desmet W., da Silva M.M. (2018) On redundancy resolution and energy consumption of kinematically redundant planar parallel manipulators, *Robotica* **36**(6): 809–821.

[2] Morlock M., Meyer N., Pick M.A., Seifried R. (2021) Real-time trajectory tracking control of a parallel robot with flexible links, *Mech Mach Theory* **158**: 104220.