Flexible models of a three degree of freedom serial elastic robot

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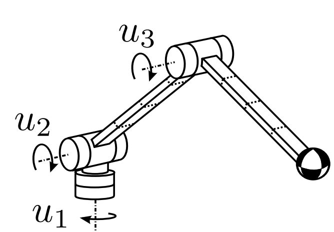
Lightweight and flexible robots have a high potential in today tendency to use collaborative automation. Thanks to their reduced weight and increased compliance, such systems benefit from an intrinsic safety that reduce the risk of injury in case of unexpected collision. However, their controller has to be carefully designed to deal properly with the flexible behavior of the links and joints.

Both feedforward and feedback actions of the controller play a role in the behavior of elastic robots. The use of a feedforward command based on a flexible model of the robot can lead to a trajectory planning of the robot with reduced vibrations see, e.g. [1]. For flexible robots performing trajectory tracking tasks, their inverse dynamics needs to be solved using some particular techniques. Devasia et al. [2] presented a stable inversion method, later applied in [3], that can deal with flexible non-linear systems. An optimal control approach is proposed in [4] for 2D flexible systems. Based on state measurements, such as strain or accelerations in the robot, coming from sensors, a feedback action can be implemented to compensate the residual vibrations see, e.g. [5, 6]. The combination of both actions can lead to a robust and precise control of the robot.

In the present work, a comparison of different methods to model a 3D flexible robot for the computation of the feedforward and feedback actions is made. This comparison is carried out for the particular case of the *ELLA* robot, shown in Fig. 1(a). This lightweight and flexible robot, built by the Institute of Robotics at the JKU in Linz, has two flexible links and three actuated degrees of freedom (dof). The computation of a feedforward action is based on the inverse dynamics of the robot, solved using the optimization approach [4] extended to 3D systems. Currently, the controller only involves a feedback action which is evaluated based on a model of the ELLA robot which models the link flexibility using lumped mass elements such as springs and dampers elements. Accelerations and velocities of the links, measured through IMUs, are fed back to insure an efficient control of the robot. A second model is based on a finite element approach and models the distributed link flexibility and joint imperfections using beam elements and kinematic joints. A representation of the finite element model is seen in Fig. 1(b). For these two models, various questions related with the control design problem are addressed including the identification of the model parameters based on experimental measurements, the computation of the feedforward action using an offline optimization algorithm as well as the design of the feedback action and its real-time implementation in the controller.

(a) ELLA robot (3 dof) from the Institute of Robotics at the JKU Linz.



(b) Finite element model of the ELLA robot.

Fig. 1: Model of the ELLA robot using 3 kinematic hinges, 8 beam elements and a point mass at its tip.

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