Disturbance rejection in periodic motion

with enhanced constant velocity transitions using a tilt-mirror test setup

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Abstract

Devising a modern control strategy that attenuates disturbances generated by periodic motion is highly appealing for a wide range of emerging nanometer precision applications [1, 2]. In this context, the authors explore the design of an appropriate control law to counteract a set of disturbances that are positive integer multiples of the fundamental frequency of the periodic reference signal. The test setup is shown in Figure 1. The motion platform consists of a carbon fiber tilting plate serving as a mirror (to reflect radiation) with moment of inertia 6.723×10^{-3} kg m^{-2} and ø 395 mm. The carbon fiber mirror is driven by a Lorentz actuator featuring contactless force transfer, whereas the guiding elements are flexure hinges. The angular displacement is measured via an optical incremental encoder and is limited to ±6 degrees. From the motion control perspective, we aim to follow the commanded reference trajectory as close as possible while minimizing the associated root mean square errors (RMSEs) with respect to the angular position and velocity. Towards this end, we have adopted a model-based control architecture comprising a feedforward controller based on model inversion and a modern feedback controller to guarantee robust stabilization and rapid disturbance rejection. The core of the disturbance rejection algorithm resorts to the L_1 adaptive augmentation with full-state feedback [3]. Accordingly, the proposed control concept features a modified prediction stage and adaptation laws [4]. The interested reader is referred to the constructive design procedure shown in [5] and its companion paper, as well as the references therein. We have completed our investigations through experimental validation, as illustrated in Figure 2. The reference trajectory (in red) consists of a continuous differentiable triangular waveform with an amplitude of 5 degrees and a frequency of 6.25 Hz (see Fig. 2, top left). The tracking performance is validated via the measured angular position (in blue) displaying a barely visible error. We therefore focus our results on the velocity error (Fig. 2, bottom left) which is the most interesting indicator in scanning tasks. The superior disturbance rejection of the proposed adaptive controller during constant velocity phases (in green) is highlighted via the relative velocity error (Fig. 2, bottom right). Note that the dashed black lines indicate the activation of the adaptive augmentation to visualize the rapid disturbance rejection.

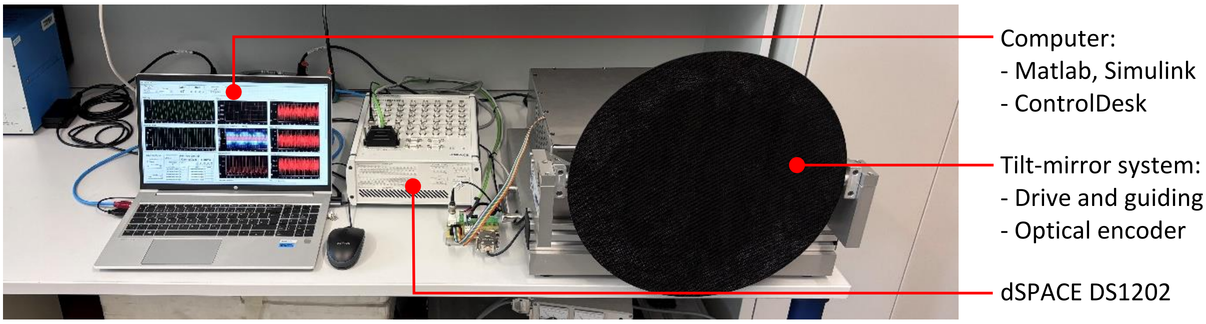

Figure 1: Photograph of the tilt-mirror test setup.

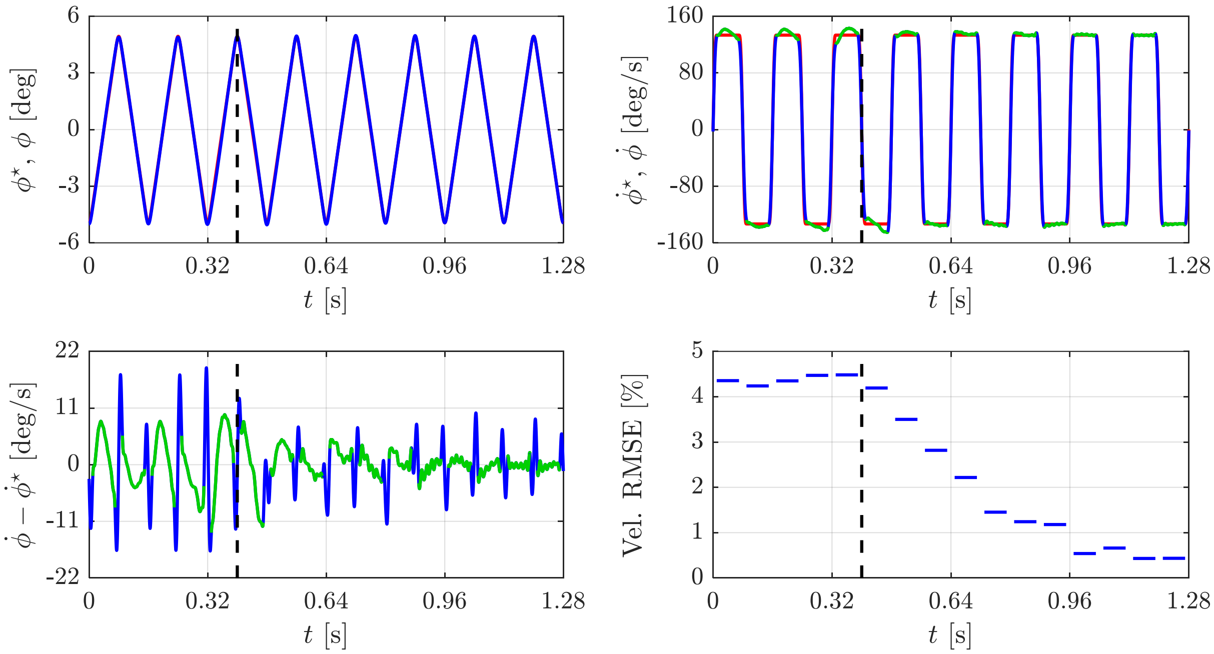

Figure 2: Time series of angular position (top left), angular velocity (top right), velocity error (bottom left), and relative velocity error (bottom right). The superscript $(\cdot)^\star$ is for desired references (in red).

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References

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