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General stabilization method of fractional-order $\text{PI}^\lambda D^\mu$ controllers for fractional-order systems with time delay. (English) [Zbl 1402.93223]

Summary: In this paper, an effective method is proposed to get the stabilizing regions of fractional-order $\text{PI}^\lambda D^\mu$ controllers for an arbitrarily given fractional-order system with time delay. For each known proportional gain ($k_p$), integral gain ($k_i$), or derivative gain ($k_d$) in the $\text{PI}^\lambda D^\mu$ controllers, the stabilizing region with respect to the other two control gains is derived respectively. The boundaries of the stabilizing regions are firstly obtained based on singular frequencies. Then, the main results are presented to directly determine the stabilizing region from an analytical viewpoint. The results avoid the time-consuming stability test since the stabilizing region is usually determined by manually choosing lots of test points from all the divided regions by the resultant boundaries. Besides, the stabilizing ($k_i, k_d$) regions of the $\text{PI}^\lambda D^\mu$ controllers for $\lambda + \mu = 2$ can be determined and the linear programming characteristic of the stabilizing ($k_i, k_d$) region for the case $\lambda + \mu = 2$ is obtained. Furthermore, the robust stabilizing region is analyzed. The results in this paper provide the basis for both the tuning of the $\text{PI}^\lambda D^\mu$ controller in practice and the design of the $\text{PI}^\lambda D^\mu$ controller satisfying different performance criteria. Numerical examples and an application example are presented to check the validity of the proposed method.

MSC:
93D21 Adaptive or robust stabilization
93C20 Control/observation systems governed by partial differential equations
35R11 Fractional partial differential equations

Keywords:
cart pendulum; fractional-order system; $\text{PI}^\lambda D^\mu$ controller; stabilizing region; time delay

Full Text: DOI