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PhD Dissertation Announcement

Digital Controller Design for Analog Transfer Function Matrices with Multiple Input-Output Time Delays

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Majority of industrial processes are described by multivariable systems with multiple time delays in the frequency domain. These multiple time delays arise mainly from transportation lags in networks, long recycle loops, and input-output lags induced by the implementation of actuators and sensors. The corresponding multivariable systems are often represented by analog transfer function matrices with multiple time delays. For the analysis and design of the multiple time-delay transfer function matrices in the continuous-time domain, a minimal realization scheme is newly developed for finding the controllable and observable continuous-time state-space model with multiple input-output time delays. For discrete-time analysis and design of the multiple time-delay system, the obtained continuous-time state-space model is discretized and an extended discrete-time state-space model is newly constructed for discrete-time linear quadratic regulator (LQR) design. For digital implementation of the newly designed digital controller, a low-order optimal digital observer is developed for the digitally controlled sampled-data multiple time-delay system.

When the time delays are sufficiently large compared to the dominant process time constant, the dimension of the developed extended discrete-time state-space model will be extremely high. As a result, numerical problems may arise for finding a digital controller. To overcome the abovementioned difficulty, an alternative digital controller design for the analog multiple time-delay transfer function matrices with long-time delays is newly developed. The multiple input-output time-delay transfer function matrices with long-time delays is minimally realized and represented by a delay-free state-space model with a multiple output-delay function. The obtained delay-free state-space model is utilized to design an analog LQR. Then, the resulting analog controller is converted to an equivalent digital controller via a state-matching digital redesign method. A low-order optimal digital observer is also designed for implementation of the digitally redesigned controller. Illustrative examples are given to demonstrate the effectiveness of the proposed methods.

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