Reduced Order Modelling of Time-Delay Systems: Past, Present and Future

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Time-Delay Systems (TDS) are also called after-effect or dead-time systems, hereditary systems, or differential-difference equations. They pertain to a class of infinite-dimensional functional differential equations (FDE). Time delays take place in a number of systems such as aircraft, chemical control systems, laser models, internet, biology, medicine etc. These delays may arise due to transport, communication or measurement.

Taking into account time delays is complicated because, in continuous time representations, they combine difference relations with differential equations, or in the Laplace domain, they are represented by exponential functions that incorporate irrational elements. It is therefore not easy to apply the principle of continuous-time control theory directly. The finite-dimensional Padé approximations for system analysis and control are a common practice of expressing time-delay systems. But it leads to a higher-order system representation for which a higher-order controller is needed. A higher-order controller cannot always be practically implementable. The requirement to reduce the order of the finite-dimensional Padé approximate model is therefore necessary. A great deal of work has already progressed in the field of reduced-order modelling for time-delay systems.

Some researchers expanded the exponential terms associated with the time-delay systems with the help of Taylor series and further the moments of the method were calculated by means of Krylov-subspace techniques. Few of them followed the H_∞ norm to solve the model reduction technique. Moreover, some researchers even applied Krylov-based technique of linear time-delay systems to yield delay-free reduced-order models. Many of the researchers worked on the balanced truncation method to develop low-order models. Even mixed approach was applied to estimate the denominator and numerator polynomials separately. In addition, the infinite dimensional delays were addressed with the help of Galerkin approximations. Few researchers suggested methods based on system expansion by orthogonal polynomials.

Although many avenues of research have been explored for the reduction of TDS orders, soft computing techniques have yet to be developed. This provides an enormous opportunity for the researchers to develop reduced-order models corresponding to the time-delay systems applying new metaheuristic algorithms. In addition, the issue of model order reduction for TDS was not simply limited to a continuous-time domain, but also attracted researchers to explore it in a discrete-time domain. However, these discrete time systems do not accept a very high sampling frequency and do not stabilize due to overcrowding of poles at the (1,0) point in the unit circle. This question can be answered if discrete time systems are formulated by the delta operator. Delta operator modelling provides a unified framework of study in which the resulting model converges at high frequency with its continuous-time counterpart.

Biography: Dr. Souvik Ganguli is presently working as the Assistant Professor in the Department of Electrical & Instrumentation Engineering, Thapar Institute of Engineering and Technology, Patiala. He has pursued B. Tech (Electrical Engineering) and M. Tech (Mechatronics) in the years 2002 and 2008 respectively. He has completed his PhD degree in system identification and control from Thapar Institute of Engineering and Technology in October 2019. He has a total of 16 years of work experience in industry, teaching and research. His research interests include model order reduction, identification and control, nature inspired metaheuristic algorithms, electronic devices and renewable energy applications. He has nearly 75 publications that have been cited over 100 times, and his publication H-index is 6 and has been serving as a reviewer of several reputed journals.

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