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PROPOSITION DE STAGE EN COURS D'ETUDES

Référence : **DTIS-2024-12**
(à rappeler dans toute correspondance)

Lieu : Toulouse

Département/Dir./Serv. : DTIS/COVNI

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DESCRIPTION DU STAGE

Thématique(s) : Identification et Commande des Systèmes

Type de stage : ☒ Fin d'études bac+5 ☒ Master 2 ☐ Bac+2 à bac+4 ☐ Autres

Intitulé : Reduction of Partial Differential Equations for time-delay compensation using Predictor-based control strategies

Sujet : Time-Delays are an unavoidable issue in today's control systems, appearing in different fields such as engineering, physics, biology, robotics, and multi-agent systems [1], [2]. As it is remarqued in [2], delays are the main cause of instability and undesired behavior of closed-loop systems. This makes challenging the design of control laws for systems with long time-delays.

Predictor-based control is an effective approach to assign a desired closed-loop behavior to dynamic systems with long delays [3]. However, to compensate the open loop delays, the control law is composed of two terms: the first term guarantees the desired transient behavior, and the second one compensates for the delay. The term which compensates for the delay is described by a Partial Differential Equation (PDE) and for the implementation has to be reduced to an Ordinary Differential Equation (ODE).

Structure-preserving reduction techniques are of great interest because the structure that guarantees stability can be preserved when using the reduced-order model instead of the original one. Methodologies that preserve the energy structure have been recently presented in the area of discretization and reduction using the finite elements method [4] and the Loewner approach [5]. Using these approaches, the reduced-order models are obtained in the form of Linear Time-Invariant (LTI) Differential Algebraic Equations (DAEs). As soon as the time-delay gets longer, the amount of states requiered for the compensation increases, making their implementation very hard for long time-delays.

The objective of this internship is to develop a model reduction methodology that obtains a Linear Time-Variant (LTV) Reduced-Order Model (ROM). The ROM has to preserve the energy structure of the initial PDE in order to use it as a guarantee of closed-loop stability. The motivation to use LTV ROMs is that they can reduce the amount of states requiered in exchange of incorporating a slight complexity related to the time-varying matrices.

The ROM proposed in the intership will be compared with the analytical solution and the methodologies mentioned previously. The proposed models will be implemented in numerical simulations using the Smith predictor strategy [6], [8] or more recent predictor-based control strategies [3], [7]. The intern will be free to propose examples where compensation of time-delays becomes essential in the fields of aerospace, robotics, multi-agents, chemistry, physics, electronics, maritime, among others.

[1] Zhang, X. M., Han, Q. L., Seuret, A., Gouaisbaut, F., & He, Y. (2019). Overview of recent advances in stability of linear systems with time-varying delays. IET Control Theory & Applications, 13(1), 1-16.

[2] Yang, R., Liu, L., & Feng, G. (2022). An overview of recent advances in distributed coordination of multi-agent systems. Unmanned Systems, 10(03), 307-325.

[3] Deng, Y., Léchappé, V., Moulay, E., Chen, Z., Liang, B., Plestan, F., & Han, Q. L. (2022). Predictor-based control of time-delay systems: a survey. International Journal of Systems Science, 53(12), 2496-2534.

[4] Cardoso-Ribeiro, F. L., Matignon, D., & Lefèvre, L. (2021). A partitioned finite element method for power-preserving discretization of open systems of conservation laws. IMA Journal of Mathematical Control and Information, 38(2), 493-533.

[5] Poussot-Vassal, C., Matignon, D., Haine, G., & Vuillemin, P. (2023, June). Data-driven port-Hamiltonian structured identification for non-strictly passive systems. In 2023 European Control Conference (ECC) (pp. 1-6). IEEE.

[6] Smith, O. J. (1959). A controller to overcome dead time. iSA journal, 6(2), 28-33.

[7] Krstic, M., & Smyshlyaev, A. (2008). Backstepping boundary control for first-order hyperbolic PDEs and application to systems with actuator and sensor delays. Systems & Control Letters, 57(9), 750-758.

[8] https://fr.mathworks.com/help/control/ug/control-of-processes-with-long-dead-time-the-smith-predictor.html

Est-il possible d'envisager un travail en binôme ? **Non**

Méthodes à mettre en oeuvre :

☒ Recherche théorique	☐ Travail de synthèse
☒ Recherche appliquée	☐ Travail de documentation
☐ Recherche expérimentale	☐ Participation à une réalisation

Possibilité de prolongation en thèse : **Oui**

Durée du stage : Minimum : 4 Maximum : 6

Période souhaitée :

PROFIL DU STAGIAIRE

Connaissances et niveau requis :	Ecoles ou établissements souhaités :
Systèmes dynamiques, élement finis, analyse numérique, Matlab.	Ecole d'ingénieur ou faculté de mathématiques appliquées.