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PROPOSITION DE STAGE EN COURS D'ETUDES

Référence : **DTIS-2025-66**
(à rappeler dans toute correspondance)

Lieu : Toulouse

Département/Dir./Serv. : DTIS/COVNI

Tél. : 05 62 25 26 14

Responsable(s) du stage : DOS REIS DE SOUZA Alex

Email. : alex.dos_reis_de_souza@onera.fr

DESCRIPTION DU STAGE

Thématique(s) : Automatique, robotique

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

Intitulé : Model Predictive Control : recent advancements, implementation and the assessment of robustness in scenarios of dynamic operation

Sujet : Model Predictive Control (MPC) [1] is an advanced, optimization-based, control technique for multi-variate nonlinear systems subject to constraints (e.g., on state and/or control inputs). Due to these features, it has been widely used both in academia and in industry, especially with increasing computational the capabilities of embedded systems.

Nowadays, there are a myriad of different MPC flavors, *e.g.*, robust [2], adaptive [3], stochastic [4], distributed [5], and learning-based [6], among others. Recently [7], attention has been given to the use of MPC within scenarios with dynamical operations, *i.e.*, where the control objective might change due to external events, conditions, or unpredicted changes in the mode of operation.

Many interesting questions arise when dynamically redefining the control objective is envisaged, for instance (i) robustness and safety against previously unknown conditions (perturbations, unknown environment), (ii) how to integrate mechanisms to translate these dynamically changing needs into MPC ingredients (constraints, costs), and, finally, (iii) how these modifications will impact the properties of MPC itself (feasibility, stability of the closed-loop, computational cost). Concerning safety and robustness, a promising direction of research is the use of set-membership estimation (such as interval observers [11] or zonotopic estimation [12]) directly in the MPC algorithm.

This internship will consist of the following tasks : (i) an extensive state-of-the-art covering the different MPC techniques, highlighting their specificities, applications, and case studies, (ii) an exhaustive implementation the selected algorithms in Matlab, along with appropriate case studies and proper documentation, (iii) identify possible gaps on the application of such techniques in contexts showing uncertainty (*e.g.,* perturbations, noise, delay), safety concerns (*e.g.,* collision with obstacles [8] or between different agents [9]), or with dynamically changing conditions (*e.g.,* changing objectives, exploitation of new information, risk-aware operations).

The case studies to be simulated when implementing and evaluating these MPC algorithms will not imposed, but a special focus is to be given to robotic systems.

The ideal candidate will have a background in mathematics or engineering, with a focus on automatic control (in French, *automatique*), and strong coding capabilities (especially in Matlab & Simulink). Given the nature of the activities, a taste for research and academic development is envisaged. Experience with learning algorithms (e.g., reinforcement learning) is not mandatory but a plus.

Bibliography :

[1] Schwenzer, M., Ay, M., Bergs, T., & Abel, D. (2021). Review on model predictive control: An engineering perspective. *The International Journal of Advanced Manufacturing Technology*, *117*(5), 1327-1349.

[2] Bemporad, A., & Morari, M. (2007). Robust model predictive control: A survey. In *Robustness in identification and control* (pp. 207-226). London: Springer London.

[3] Lorenzen, M., Allgöwer, F., & Cannon, M. (2017). Adaptive model predictive control with robust constraint satisfaction. *IFAC-PapersOnLine*, *50*(1), 3313-3318.

[4] Mesbah, A. (2016). Stochastic model predictive control: An overview and perspectives for future research. *IEEE Control Systems Magazine*, *36*(6), 30-44.

[5] Christofides, P. D., Scattolini, R., De La Pena, D. M., & Liu, J. (2013). Distributed model predictive control: A tutorial review and future research directions. *Computers & Chemical Engineering*, *51*, 21-41.

[6] Hewing, L., Wabersich, K. P., Menner, M., & Zeilinger, M. N. (2020). Learning-based model predictive control: Toward safe learning in control. *Annual Review of Control, Robotics, and Autonomous Systems*, *3*(1), 269-296.

[7] Köhler, J., Müller, M. A., & Allgöwer, F. (2024). Analysis and design of model predictive control frameworks for dynamic operation—An overview. *Annual Reviews in Control*, *57*, 100929.

[8] S. Bertrand, J. Marzat, H. Piet-Lahanier, A. Kahn, Y. Rochefort. MPC Strategies for Cooperative Guidance of Autonomous Vehicles. *Aerospace* Lab, 2014, 8, pp.1-18.

[9] dos Santos, M. A., Ferramosca, A., & Raffo, G. V. (2024). Set-point tracking MPC with avoidance features. *Automatica*, *159*, 111390.

[10] Le, V. T. H., Stoica, C., Alamo, T., Camacho, E. F., & Dumur, D. (2013). *Zonotopes: From guaranteed state-estimation to control*. John Wiley & Sons.

[11] de Souza, A. D. R., Efimov, D., & Raïssi, T. (2021). Robust output feedback MPC for LPV systems using interval observers. *IEEE Transactions on Automatic Control*, *67*(6), 3188-3195.

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 : 5 Maximum : 6

Période souhaitée : début février/mars 2025

PROFIL DU STAGIAIRE

Connaissances et niveau requis :	Ecoles ou établissements souhaités :
- Bon niveau d'anglais - Bonnes connaissances en automatique (e.g., estimation, commande linéaire et non-linéaire) et mathématiques (calculus et optimisation) - Matlab & Simulink avancés - Goût pour la recherche académique est souhaitable - Connaissances en algorithmes d'apprentissage ne sont pas obligatoires mais comptent comme un plus	