logo

PhD Position : Unknown Input Observers for an efficient management of hydrographical networks based on Predictive Control

1 - Context and funding

Hydrographical networks are large scale systems composed of natural rivers and artificial canals. They are used to answer Human's needs in terms of irrigation, navigation, drinking water, industry. As environmental systems, they are disturbed by several factors due to Human's activities and extreme climate events.

In automation and artificial intelligence, control *strategies have been designed to reject these disturbances and guarantee the management objectives (*Lozenguez et al., 2018)*. It consists in controlling hydraulic devices (gates, weir, pumping stations), which allow to dispatch water to guarantee the needs and avoiding floods. For irrigation systems, it is useful to well estimate and predict withdraws; for navigation systems, to well estimate and anticipate flows due to rainfall (*Sadowska et al. 2018; Gu et al., 2018; Hadid et al., 2020). *Even if predictive control strategies have been designed (Segovia et al., 2021b)., it is still possible to improve their performances with a good estimation and prediction of uncontrolled factors. It is of the utmost importance especially in the current climate change context.*

Existing methods aims at estimating the unknown inputs/outputs based on H∞ observer (Bedjaoui et al., 2006), *Kalman filter* (Barthélémy et al., 2021; Bedjaoui et al., 2009; Bedjaoui et al., 2011)*, or Moving Horizon Estimation (MHE) technique (Guekam et al. 2021; Segovia et al., 2019). However, new advanced methods based on data-driven for the estimation and prediction of unknown inputs* inputs (injections, withdrawal, leaks, infiltration and evaporation or water) *are required (Langueh et al., 2020; Barbot et al., 2009). Based on better estimation, localization and prediction of the disturbances, the predictive control strategies could reach to an efficient management of hydrographical networks.*

Some benchmarks, already developed, will be used to achieve this research; a laboratory canal of 5m with 1 reach, canal with three 15m branches, 12m canal with flow from 0 to 150l/s, real irrigation and navigation systems located in the north and south of France.

2 - Research project

The design of observers (smart sensors) has to deal with the characteristics and complex dynamics of these systems, i.e. large scale, nonlinearity, variable delays, attenuation, etc. Given the inherently complex nature of hydrographical networks, designing observers by assuming linear dynamics may not be reasonable. Instead, the step aims first at designing unknown input observers by considering nonlinear dynamics, second at using this information to improve the predictive control of inland waterways. Based on the good estimation of unknown inputs, the model predictive control (MPC) framework will be employed to guarantee the management objectives, as it offers a number of features that are suitable to deal with hydrographical networks. The methods will be tested by using a simulator coupling MATLAB and SIC^2. The main objective consists in:

i) proposing from real and simulation data, a realistic and usable model of a hydrographical network system (carry out a comparative study of the data-based approach (Moore K. J., 2019) and the physics-based approach);

ii) achieving a follow-up of field tests on the proposed benchmarks to build a database on which new algorithms will be designed and tested;

iii) developing some methods to tune and develop news modules in the Software SIC^2 to get digital twins of real systems,

iv) designing a new approach of unknown input observers for the efficient control of hydrographical networks in centralized/decentralized/distributed approaches (Koenig et al., 2005),

v) designing a new optimal model predictive control (Segovia et al., 2021a),

vi) publishing contributions and results in conferences and scientific journals.

Key-words*: Large-scale networked systems, hydrographical networks, irrigation systems, inland waterways, Observer, Unknown input, Model Predictive Control.*

3 -Team supervision and PhD registration

Location : CERI Systèmes Numériques, IMT Nord Europe (Douai) and IRSTEA Montpellier, France.
Supervisors : Gilles Belaud (IRSTEA), Eric Duviella (IMT Nord-Europe)

4 - Candidate profile

Required skills:
- Background in programming (C, Python, Matlab)
- Background in modelling, mathematical/data models, data-driven control systems, output analysis (observation) and optimization; Environmental systems, Water systems.
- Good level of English (B2 level or higher).

5 - How to apply

Send by mail: CV, cover letter, M1 and M2 transcripts and recommendation letters (optional) to :
- Gilles Belaud, IRSTEA (gilles.belaud@supagro.fr)
- Eric Duviella, IMT Nord-Europe (eric.duviella@imt-nord-europe.fr)

6 – References

1- *Barbot J.P. et al. « An observation algorithm for nonlinear systems with unknown inputs", (2009), Automatica, Volume 45, Issue 8, Pages 1970-1974.*
2- *Barthélémy S., S. Ricci, O. Pannekoucke, O. Thual, P.-O. Malaterre « Data assimilation on a flood wave propagation model: emulation of a Kalman filter algorithm », (2012), Simhydro, Nice,France*
3- *Bedjaoui N., Litrico X., Koenig D., Malaterre P.O. « H∞ observer for time-delay systems application to FDI for irrigation canals", (2006) Proceedings of the IEEE Conference on Decision and Control, art. no. 4177859, pp. 532 – 537.*
4- *Bedjaoui N., Weyer E., Bastin G. "Methods for the localization of a leak in open water channels", (2009), 4 (2), pp. 189 – 210*
5- *Bedjaoui N., Weyer E. "Algorithms for leak detection, estimation, isolation and localization in open water channels", (2011), 19 (6), pp. 564 – 573*
6- *Gu, W., Y. Jianyong, Y. Zhikai, Z. Jingzhong. "Output feedback model predictive control of hydraulic systems with disturbances compensation", (2018), ISA Transactions. 88*
7- *Guekam P., Segovia P., Etienne L., Duviella E. « Hierarchical model predictive control and moving horizon estimation for open-channel systems with multiple time delays", (2021), pp. 198 - 203*
8- *Hadid B., E. Duviella, S. Lecoeuche. « Data-driven modeling for river flood forecasting based on a piecewise linear ARX system identification", (2020), Journal of Process Control, Volume 86, Pages 44-56.*
9- *Koenig D., Bedjaoui N., Litrico X. "Unknown input observers design for time-delay systems application to an open-channel", (2005), art. no. 1583087, pp. 5794 – 5799*
10- *Langueh K., G. Zheng and T. Floquet. "Fixed-time sliding mode-based observer for non-linear systems with unknown parameters and unknown inputs ». IET Control Theory & Applications, Volume 14, Issue 14, (2020), p. 1920 - 1927.*
11- *Lozenguez G., P. Segovia Castillo, G. Desquesnes, A. Doniec, E. Duviella, et al. "Management tools to study and to deal with effects of climate change on inland waterways", (2018), Academic Open Internet Journal, Bourgas University, Technical College.*
12- *Moore K. J., "Characteristic nonlinear system identification: A data-driven approach for local nonlinear attachments", Mechanical Systems and Signal Processing, Volume 131, pp. 335-347,2019*
13- *Sadowska A., L. Steenson and M. Hedlund. "Model-Predictive Control of a Compliant Hydraulic System,", (2018), UKACC 12th International Conference on Control (CONTROL), pp. 388-388, doi: 10.1109/CONTROL.2018.8516830.*
14- *Segovia P., Rajaoarisoa L., Nejjari F., Duviella E., Puig V. « Model predictive control and moving horizon estimation for water level regulation in inland waterways", (2019) Journal of Process Control, 76, pp. 1 – 14*
15- *Segovia P., Puig V., Duviella E. « Set-membership-based distributed moving horizon estimation of large-scale systems", (2021a), ISA Transactions.*
16- *Segovia P., Puig V., Duviella E., Etienne L. « Distributed model predictive control using optimality condition decomposition and community detection", (2021b), Journal of Process Control, Volume 99, pp. 54 – 68*